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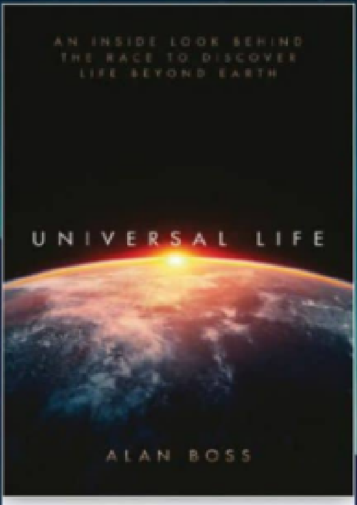
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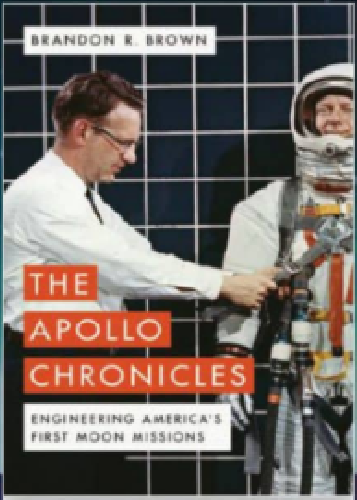

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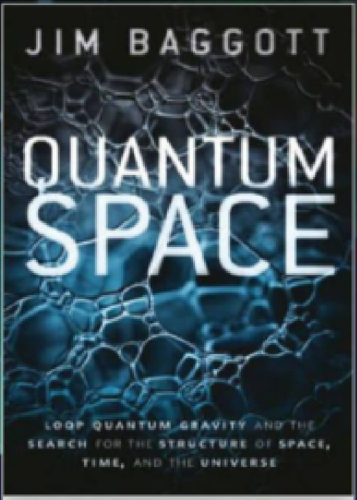
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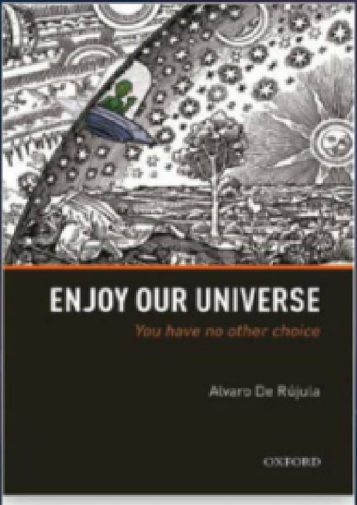

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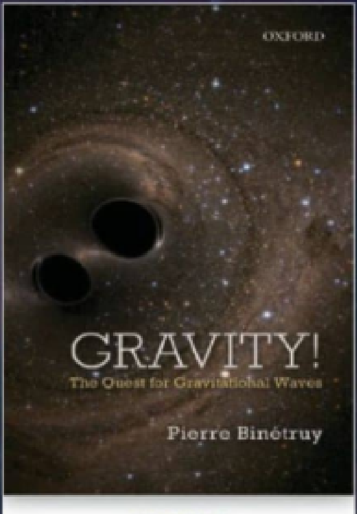

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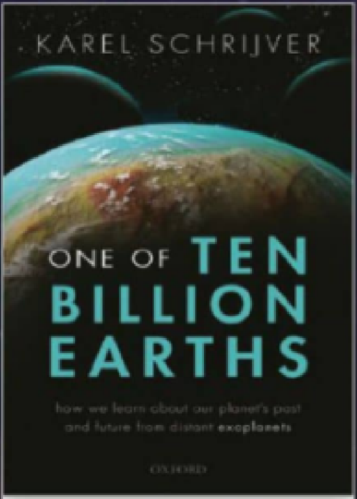
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Have we finally measured the mass of the Milky Way?

Welcome

If you hadn't noticed already, **All About Space** is an impressive 90 issues old - to celebrate the occasion we've teamed up with HarperCollins to give you a free copy of the *2019 Guide to the Night Sky*, packed with tips, tricks and advice on what to observe and when throughout the following months of the year. Written and illustrated by astronomers Storm Dunlop and Wil Tirion, it's the perfect guide for all levels of astronomer - from those just making their first tentative steps into exploring the heavens to those who are veterans of sky-watching and just need that quick reference.

Our space myths busted series continues this month as astronomers reveal what likely caused a sonic boom, tipped to be some six-times 'louder' than expected, to tear through the cosmos - I am, of course, talking about the space roar. Turn to page 16 for all of the answers, revealed by none other than the astrophysicists who have been relentlessly studying it for years.

Elsewhere this issue we caught up with the Messaging Extraterrestrial Intelligence (METI)'s Florence Raulin-Cerceau, who reveals more about the effort to communicate with alien life - in fact, she believes that we could have already been detected! We just need to find out for sure and answer back.

If you're a subscriber, we hope you enjoy your first special copy of **All About Space**.

Gemma Lavender
Editor-in-Chief

Our contributors include...

Giles Sparrow
Space science writer
If you've ever wanted a quick cheat sheet to rocket science, then look no further – Giles provides an easy, everything-you-need-to-know guide.

Lee Cavendish
Staff writer
Before we reach the 50th anniversary of Apollo 11, Lee relives the emotion, adventure and science of Apollo 10 and remembers crew member Gene Cernan.

James Romero
Science writer
Should we stop following the water when it comes to searching for alien life? James' report suggests so, as he discovers why organics on worlds like Titan could be fruitful.

Stuart Atkinson
Astronomer
It might be the end of the longer nights, but Stuart has the best tips and tricks to make the most of early summer's targets – whether you have a telescope or not.

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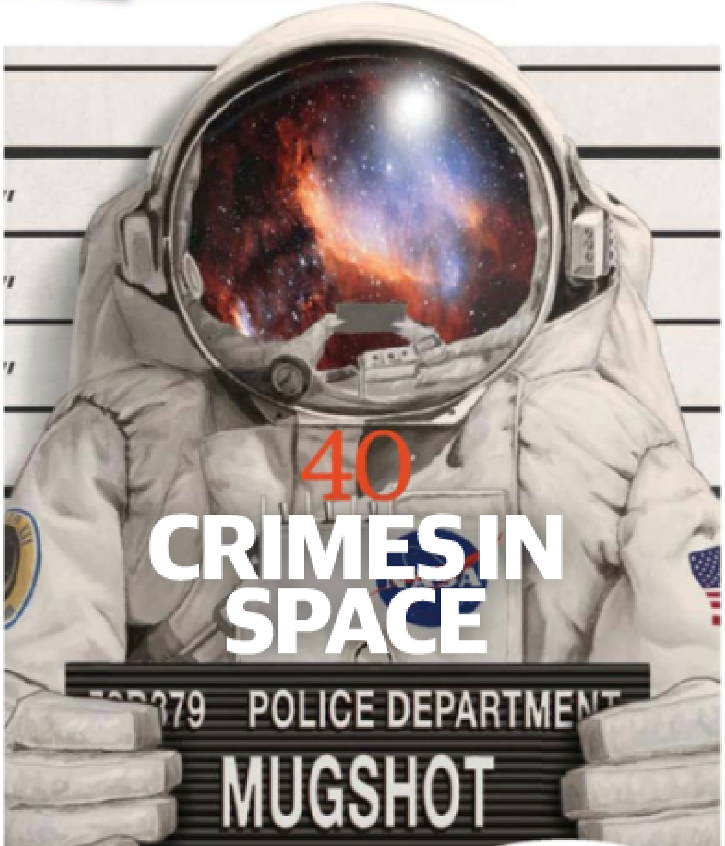

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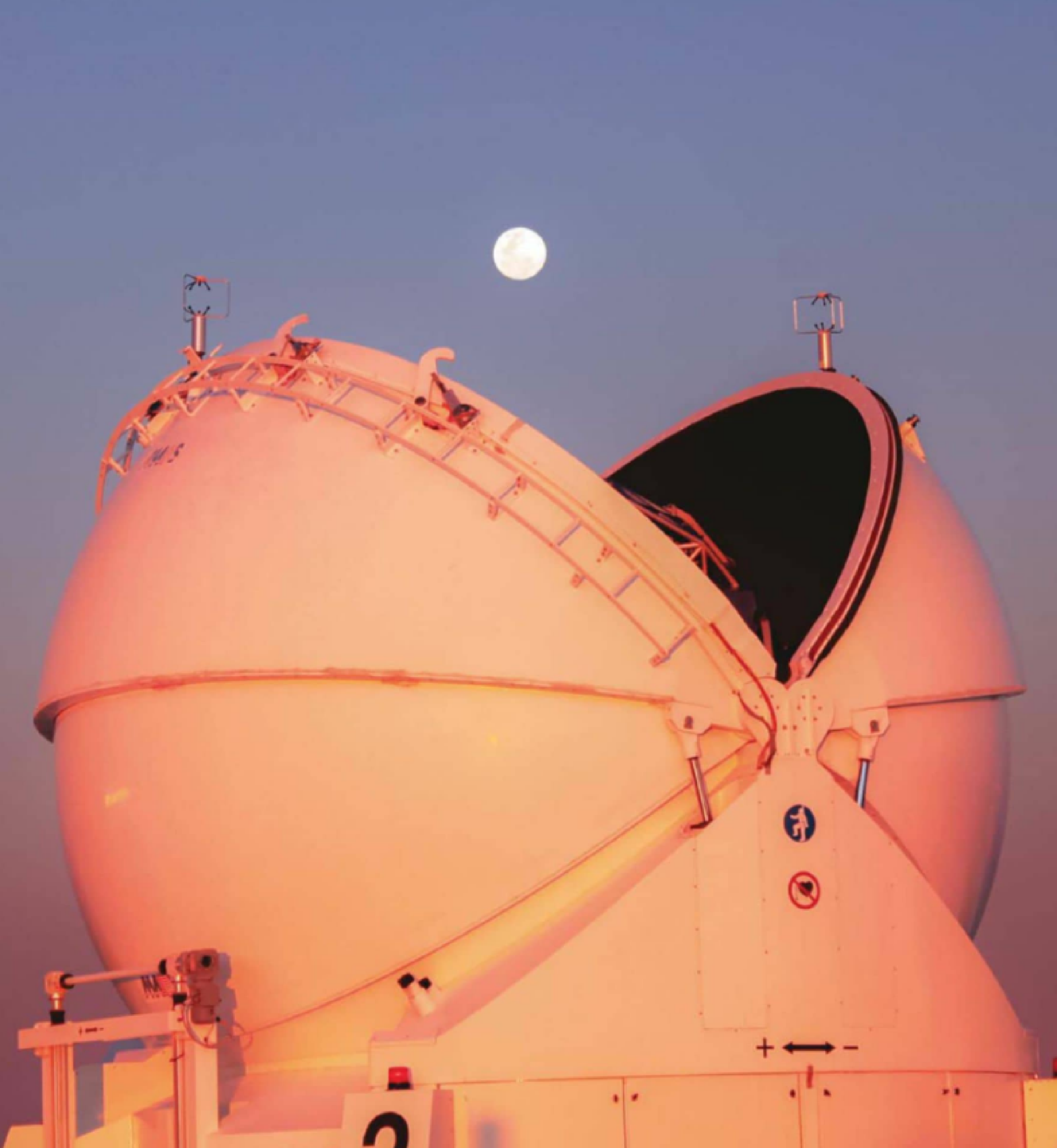
Pac-Man eats the Moon!

The classic arcade game *Pac-Man* has remained popular since 1980, and its imagery is something most will recognise. Images such as this one combine the beauty of observatories and astronomy with the most unexpected of events. In this instance, one of the Very Large Telescope's Auxiliary Telescopes starts to open its mouth as it prepares for a long night of astronomical observations. Sitting above the 'mouth', and looking like it's going to be eaten by a half-telescope, half-Pac-Man, is our natural satellite during its full phase.



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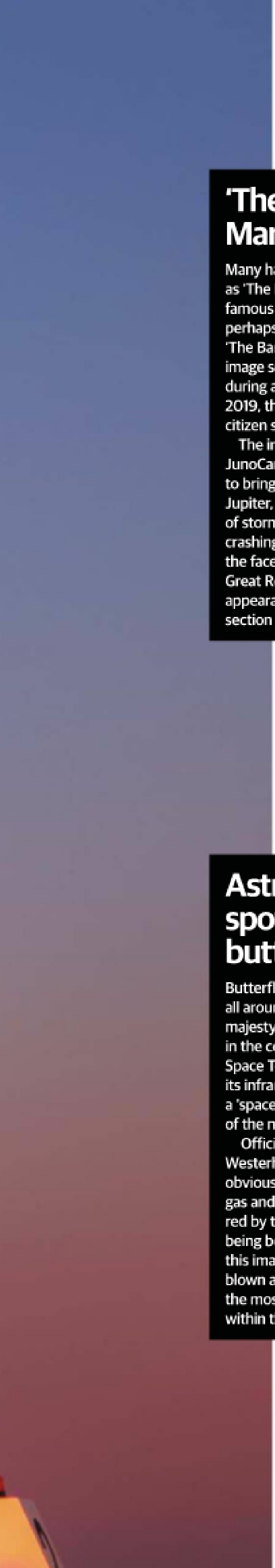
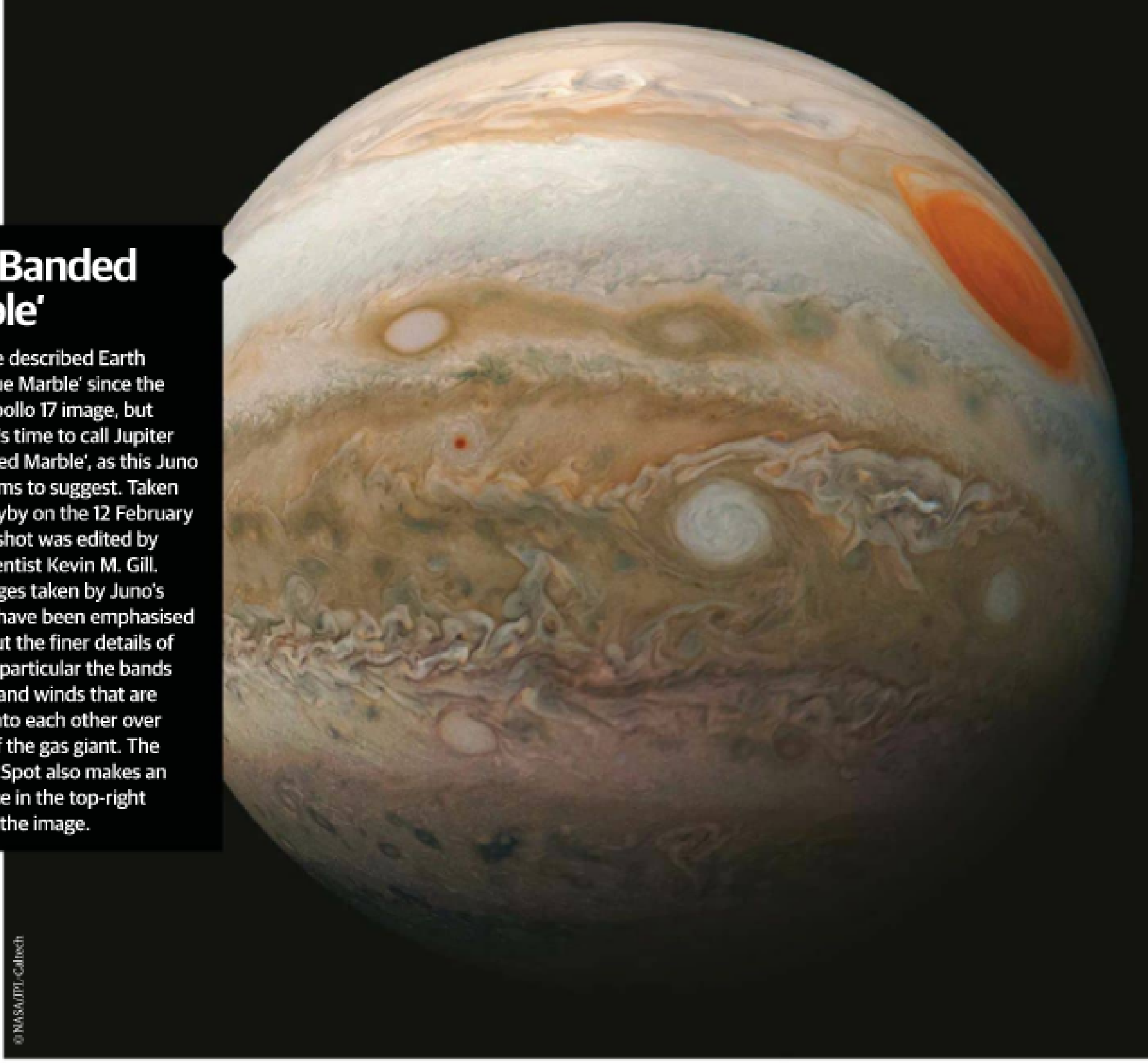


'The Banded Marble'

Many have described Earth as 'The Blue Marble' since the famous Apollo 17 image, but perhaps it's time to call Jupiter 'The Banded Marble', as this Juno image seems to suggest. Taken during a flyby on the 12 February 2019, the shot was edited by citizen scientist Kevin M. Gill.

The images taken by Juno's JunoCam have been emphasised to bring out the finer details of Jupiter, in particular the bands of storms and winds that are crashing into each other over the face of the gas giant. The Great Red Spot also makes an appearance in the top-right section of the image.



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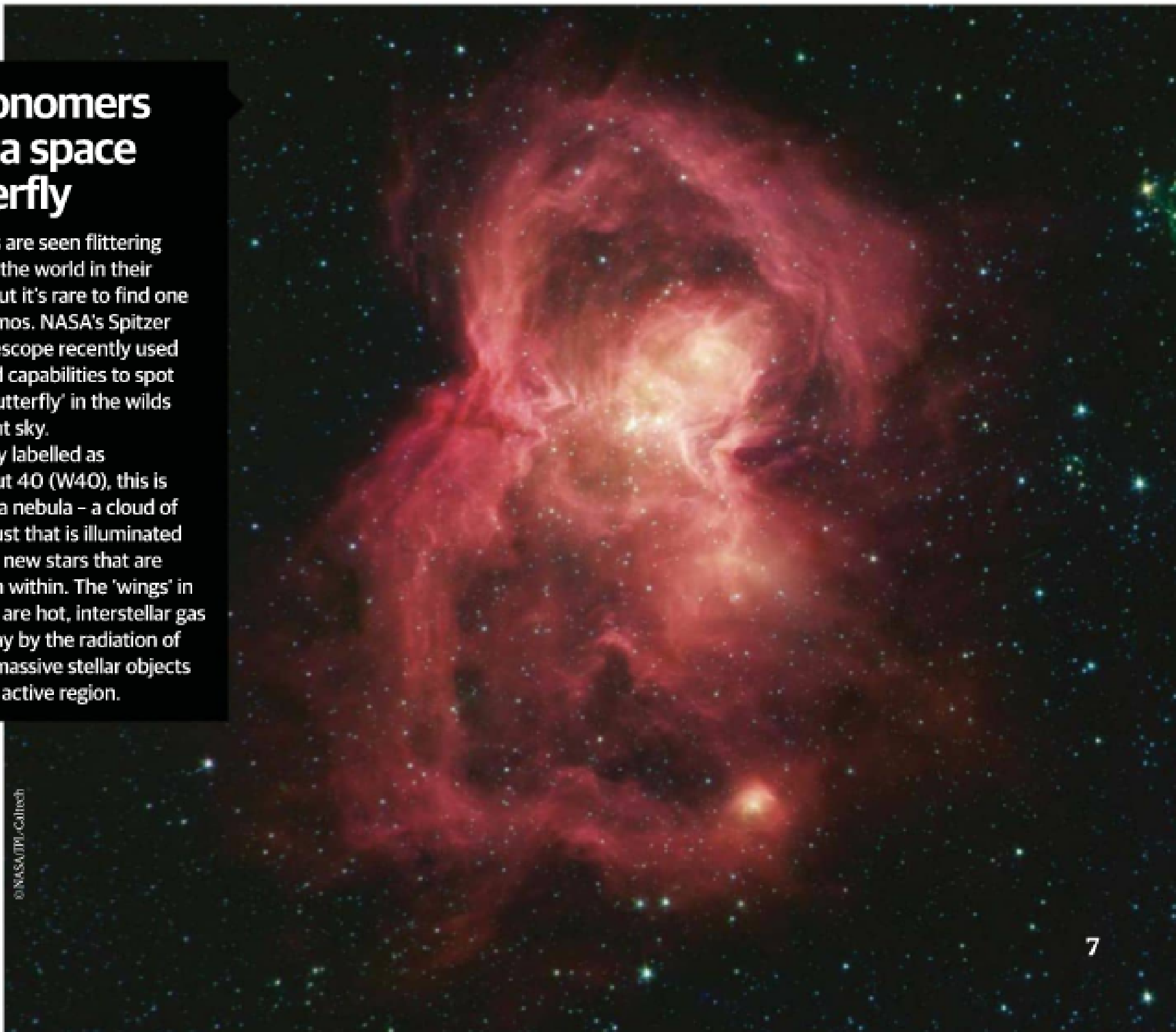
Astronomers spot a space butterfly

Butterflies are seen flittering all around the world in their majesty, but it's rare to find one in the cosmos. NASA's Spitzer Space Telescope recently used its infrared capabilities to spot a 'space butterfly' in the wilds of the night sky.

Officially labelled as Westerhout 40 (W40), this is obviously a nebula – a cloud of gas and dust that is illuminated red by the new stars that are being born within. The 'wings' in this image are hot, interstellar gas blown away by the radiation of the most massive stellar objects within the active region.



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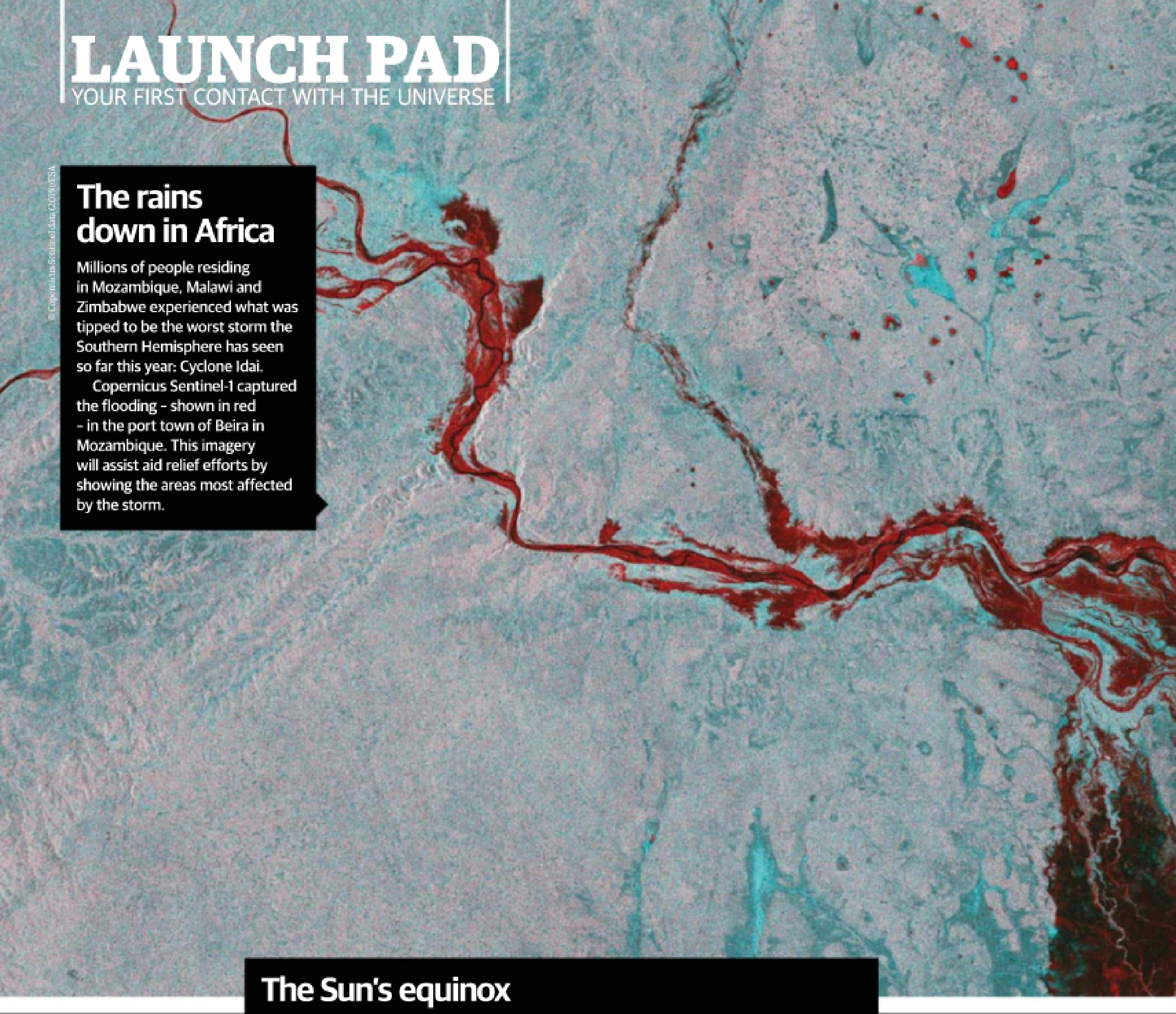

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The rains down in Africa

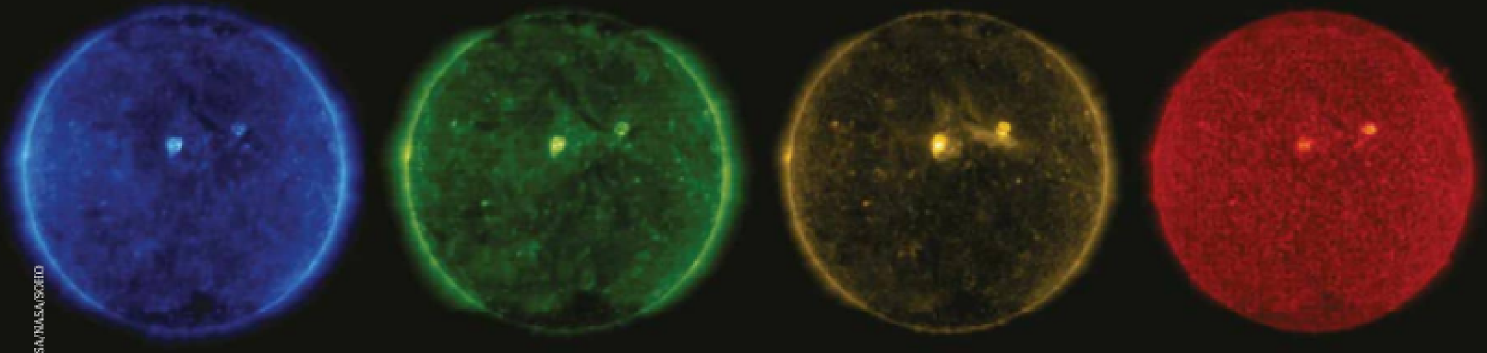
Millions of people residing in Mozambique, Malawi and Zimbabwe experienced what was tipped to be the worst storm the Southern Hemisphere has seen so far this year: Cyclone Idai.

Copernicus Sentinel-1 captured the flooding – shown in red – in the port town of Beira in Mozambique. This imagery will assist aid relief efforts by showing the areas most affected by the storm.

The Sun's equinox

20 March marked the annual spring equinox, marking the beginning of warmer seasons in the Northern Hemisphere. The recent change in events also saw the ESA/NASA Solar and Heliospheric Observatory (SOHO) capture the Sun in different wavebands.

From left to right, SOHO observed the Sun in 171 angstroms, 195 angstroms, 284 angstroms and 304 angstroms wavelengths respectively, which all correspond to different parts of the ultraviolet section of the electromagnetic spectrum.



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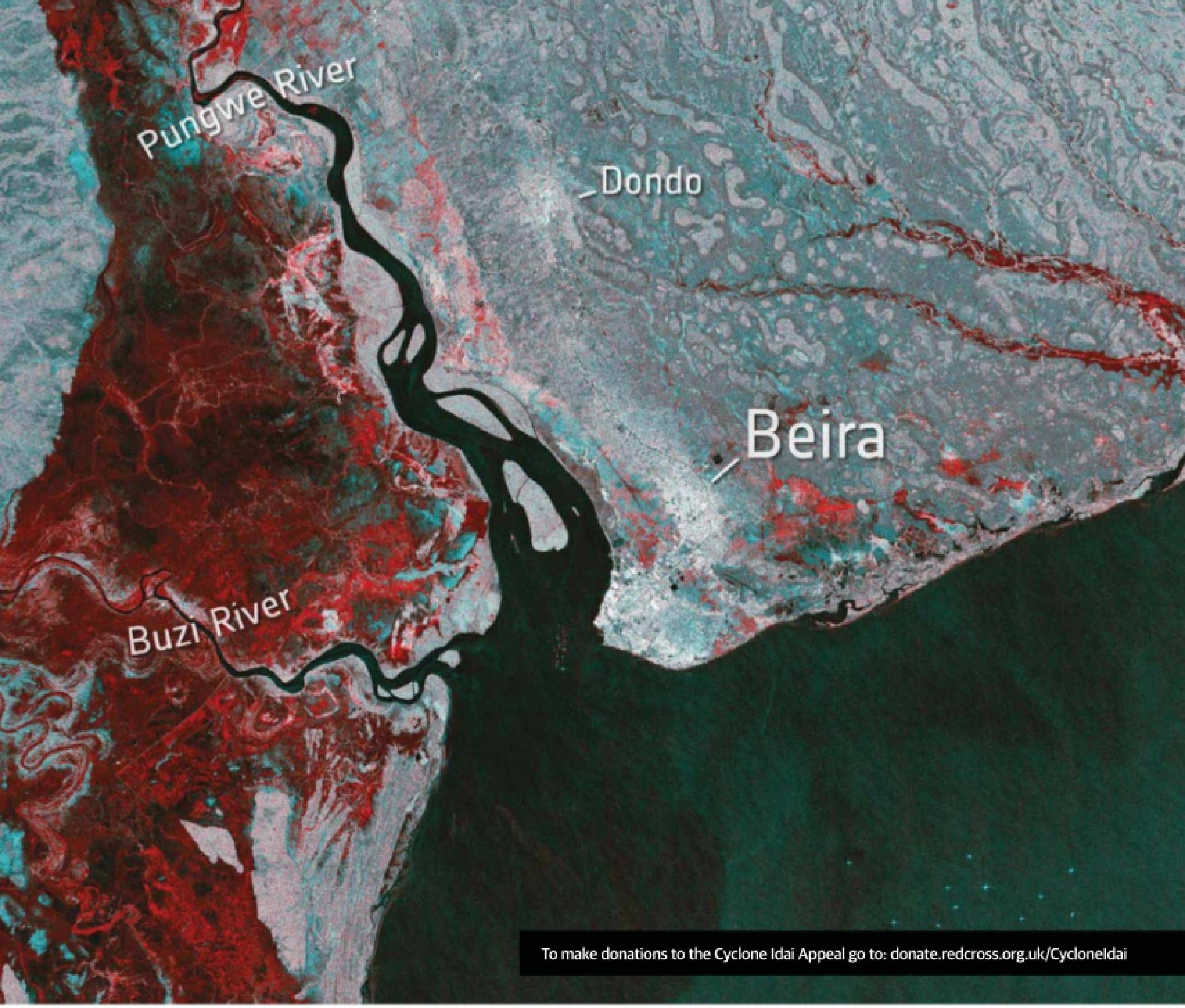
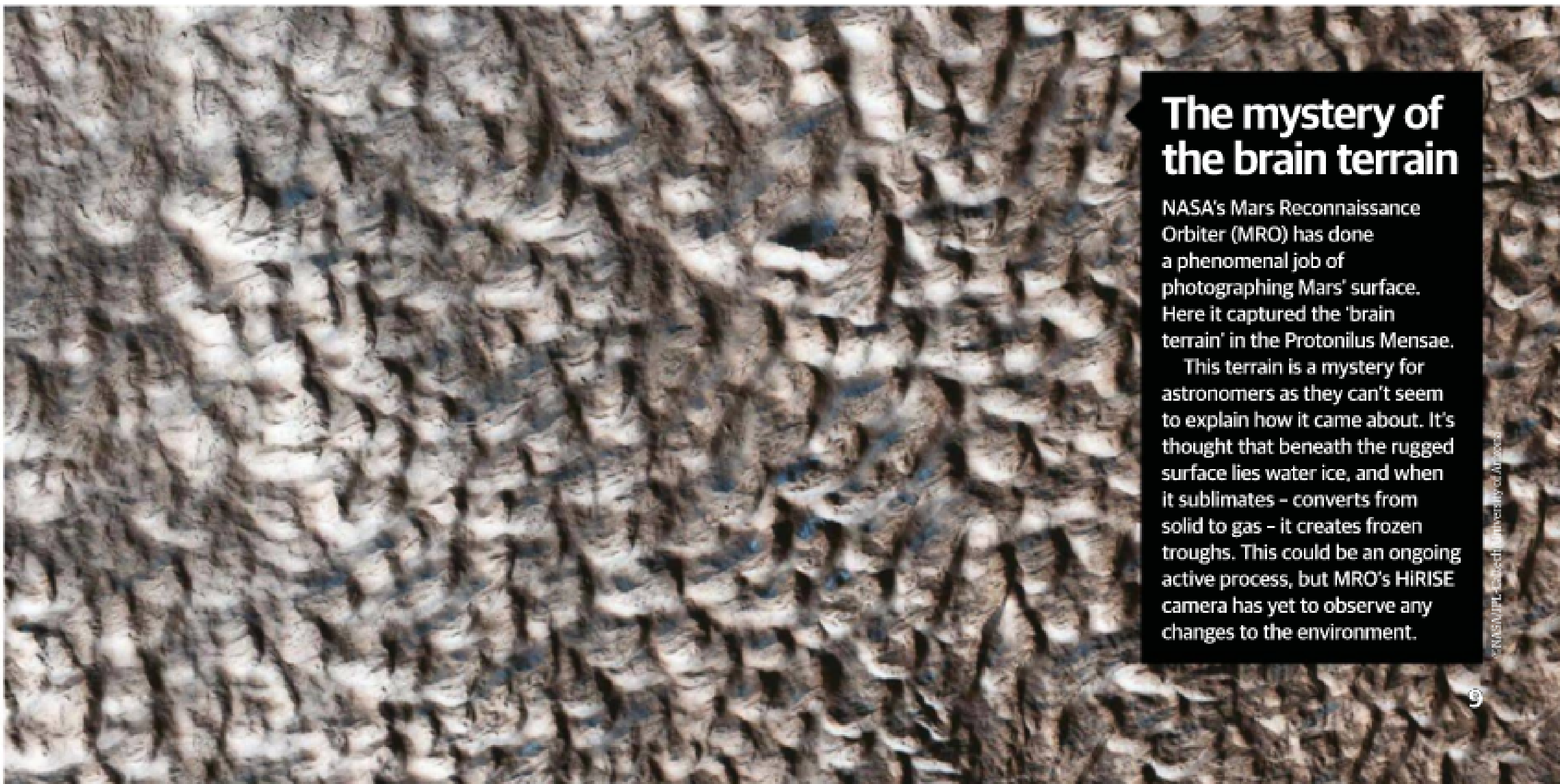


To make donations to the Cyclone Idai Appeal go to: donate.redcross.org.uk/CycloneIdai



The mystery of the brain terrain

NASA's Mars Reconnaissance Orbiter (MRO) has done a phenomenal job of photographing Mars' surface. Here it captured the 'brain terrain' in the Protonilus Mensae.

This terrain is a mystery for astronomers as they can't seem to explain how it came about. It's thought that beneath the rugged surface lies water ice, and when it sublimates – converts from solid to gas – it creates frozen troughs. This could be an ongoing active process, but MRO's HiRISE camera has yet to observe any changes to the environment.

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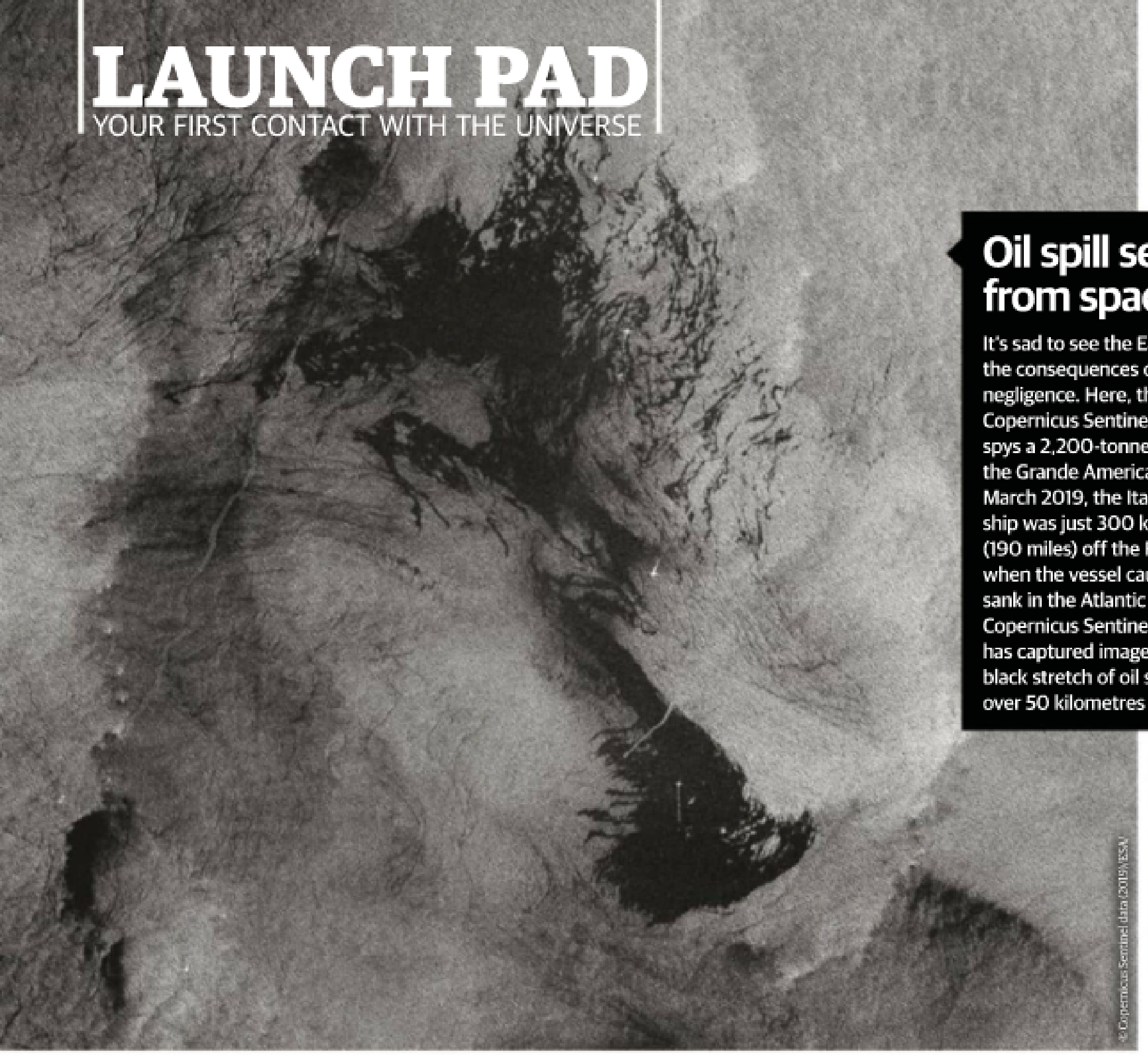

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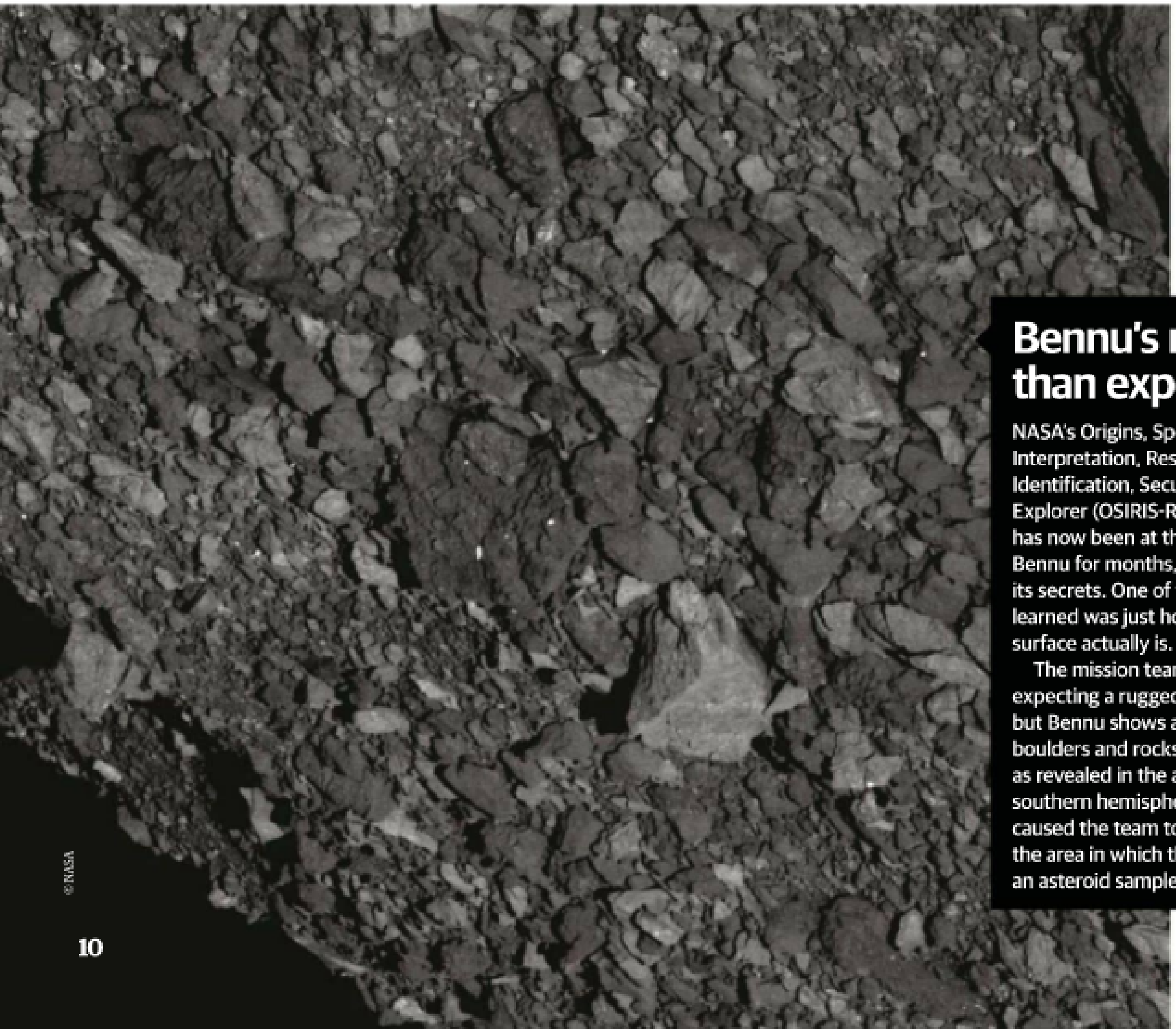
Oil spill seen from space

It's sad to see the Earth suffer the consequences of human negligence. Here, the ESA's Copernicus Sentinel-1 satellite spys a 2,200-tonne oil spill from the Grande America vessel. On 12 March 2019, the Italian container ship was just 300 kilometres (190 miles) off the French coast when the vessel caught fire and sank in the Atlantic Ocean. The Copernicus Sentinel-1 satellite has captured images of the huge, black stretch of oil spread out over 50 kilometres (30 miles).



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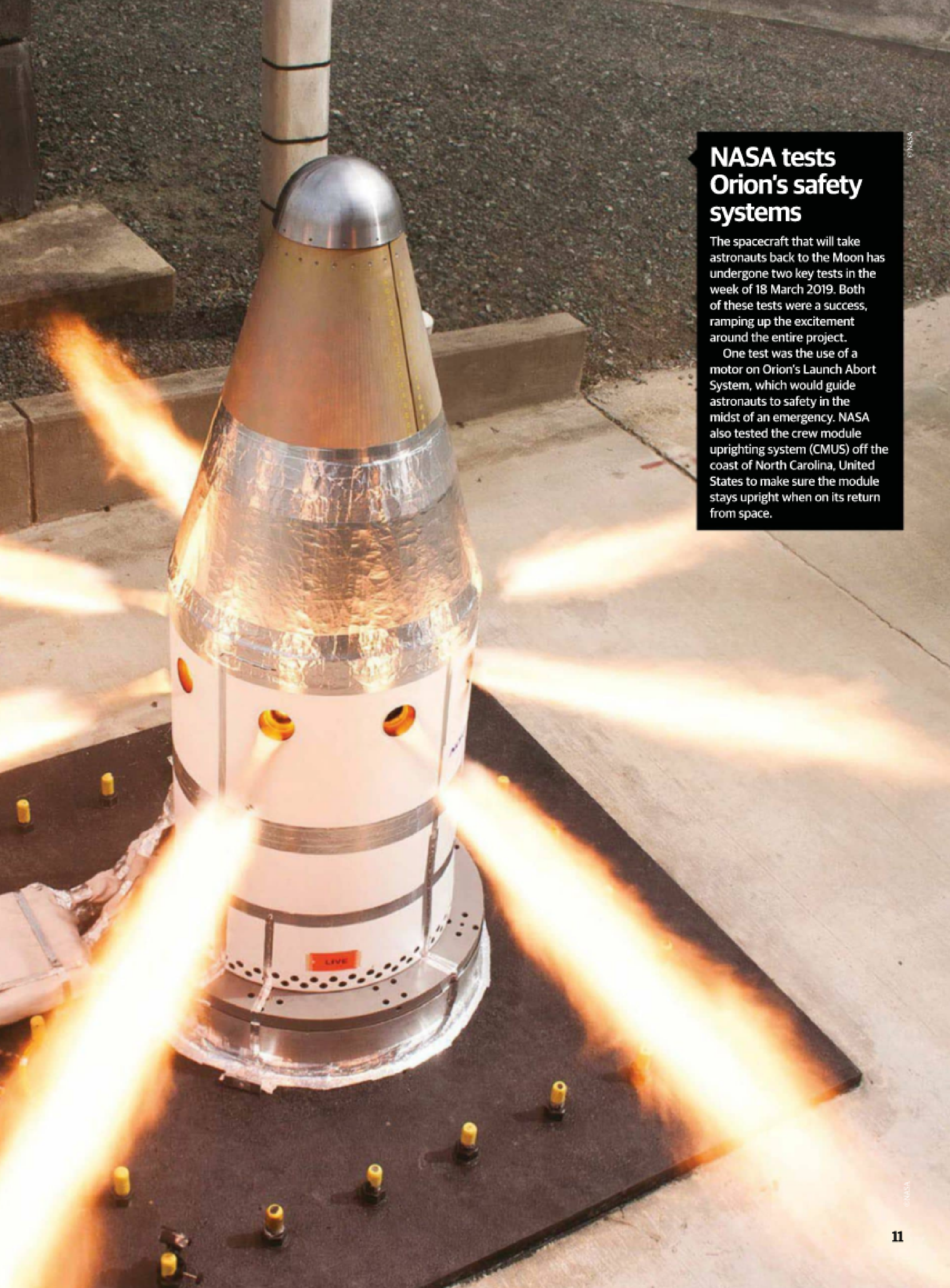
Bennu's rockier than expected

NASA's Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (OSIRIS-REx) spacecraft has now been at the asteroid Bennu for months, trying to learn its secrets. One of the things learned was just how bumpy the surface actually is.

The mission team were expecting a rugged surface, but Bennu shows a flurry of boulders and rocks all over, as revealed in the asteroid's southern hemisphere. This has caused the team to re-evaluate the area in which they will collect an asteroid sample.



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NASA tests Orion's safety systems

The spacecraft that will take astronauts back to the Moon has undergone two key tests in the week of 18 March 2019. Both of these tests were a success, ramping up the excitement around the entire project.

One test was the use of a motor on Orion's Launch Abort System, which would guide astronauts to safety in the midst of an emergency. NASA also tested the crew module uprighting system (CMUS) off the coast of North Carolina, United States to make sure the module stays upright when on its return from space.

An artist's impression of the Big Bang

Massive clock-like particles could reveal what happened before the Big Bang

Words by **Charles Q. Choi**

To see if there was a universe before the Big Bang and understand how the cosmos evolved after it began, researchers suggest looking for the influence of particles that acted like clocks.

Currently, the prevailing view in cosmology is that in the first few moments of the universe, the cosmos experienced an incredible burst of expansion known as inflation. During this growth spurt, space itself expanded faster than the speed of light.

Inflation can help solve a variety of mysteries about the structure and evolution of the cosmos. For example, inflation would have evened out the universe's composition, explaining why it looks mostly the same in every direction.

Critics of the inflationary theory of cosmology argue that it requires unlikely starting conditions for the universe and that increasingly contrived models are needed for inflation to explain the latest data on the cosmic microwave background radiation, the universe's oldest light, said study co-author Avi Loeb, chair of astronomy at Harvard University.

"The most natural, plausible models of inflation have been ruled out," said Loeb. "And a very flexible theory of inflation that can accommodate any scenario, where everything is possible, is a bit worrisome – the strength of a scientific theory is that it can predict certain outcomes and rule out others."

Scientists have developed other, very different cosmological models that may solve the same cosmic mysteries that inflation does. For example, inflation assumes the universe began as a singularity, an infinitely dense point of matter and energy. In theory, singularities curve the fabric of space and time to an infinite extent, such that nothing existed before the Big Bang, not even time. However, another cosmological model suggests that the cosmos was born from a 'Big Bounce', expanding outward after an earlier primordial universe collapsed. Like inflation, this model can explain why the universe looks the way it does, Loeb said. Now, to help decide between inflation and these other ideas, Loeb and his colleagues have suggested a test to see if they are potentially false.

The key to this test is how the universe behaves in these different cosmological models, said study co-author Zhong-Zhi Xianyu of Harvard University. Inflation suggests that the universe expanded exponentially, while the Big Bounce posits that a primordial universe contracted and then our current universe expanded; some models conjectured that any change in size happened very slowly, while others proposed it occurred very quickly.

If a primordial universe existed before our cosmos, our current understanding of physics suggests massive particles would have existed that would have oscillated at some regular frequency, like a clock's pendulum. The fluctuations of these 'primordial clocks' would have resulted in tiny irregularities in the density of matter on minuscule scales that would have become the seeds of structures on cosmic scales in our universe after it expanded.

If a primordial universe once existed, its collapse would have squeezed the ticking primordial standard clocks in ways that one might detect in the structure of the current universe.

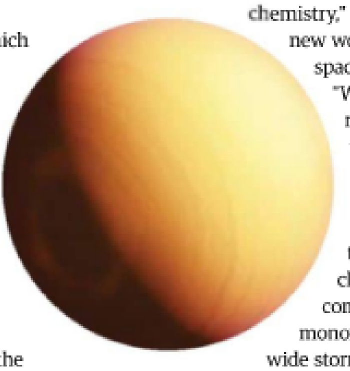
© NASA's Goddard Space Flight Center/ ESO; ESA

Violent planet-wide storm spotted above distant exoplanet

Words by **Samantha Mathewson**

New data from the European Southern Observatory (ESO) shows raging storm clouds of iron and silicates swirling above a distant exoplanet. The exoplanet, HR 8799 e, orbits a young star called HR 8799, which is about 1.5-times the size of the Sun and about 129 light years from Earth in the constellation Pegasus.

HR 8799 e was first discovered in 2010, and is the innermost star of the HR 8799 system. An estimated 30 million years old, this exoplanet is believed to be about nine-times the mass of Jupiter and takes approximately 45 Earth years to orbit its parent star.



Using the GRAVITY instrument on the ESO's Very Large Telescope Interferometer (VLTI), astronomers uncovered the complex atmosphere of this storm-wracked exoplanet.

The GRAVITY instrument employs a technique called optical interferometry, which uses the light of four telescopes to see features that are ten-times more detailed than was previously possible, according to a statement from the ESO.

"Our analysis showed that HR8799 e has an atmosphere containing far more carbon monoxide than methane – something not expected from equilibrium chemistry," Sylvestre Lacour, lead author on the new work and a researcher from the French space agency CNRS, said in the statement. "We can best explain this surprising result with high vertical winds within the atmosphere preventing the carbon monoxide from reacting with hydrogen to form methane."

The new data also revealed that the exoplanet's atmosphere contains clouds of iron and silicate dust which, combined with an excess of carbon monoxide, suggests there is a violent planet-wide storm.

"Our observations suggest a ball of gas illuminated from the interior, with rays of warm light swirling through stormy patches of dark clouds," Lacour said. "Convection moves around the clouds of silicate and iron particles, which disaggregate and rain down into the interior. This paints a picture of a dynamic atmosphere of a giant exoplanet at birth, undergoing complex physical and chemical processes."

Astronauts help discover newfound crustacean during cave expedition

Words by **Mike Wall**

In training for exploration of the final frontier, astronauts have made a contribution to our understanding of life here on Earth. Over the past few years astronauts from multiple countries have helped biologists collect specimens of an odd, tiny crustacean during caving expeditions on the Italian island of Sardinia. The little beast, it turns out, was new to science.

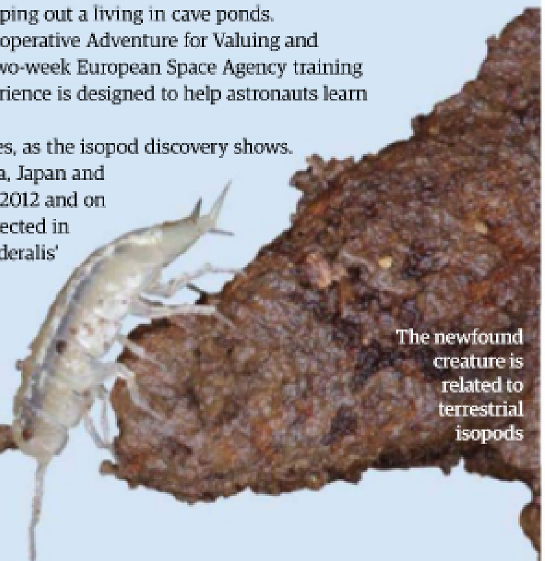
The newfound creature is related to terrestrial isopods, a diverse group known to anyone who has ever flipped a log in damp environments. Their many common names – potato bug, pill bug, sow bug, roly-poly and woodlouse, to name but a few – are a testament to these invertebrates' ubiquity. But the 'bug' part is incorrect; isopods are more closely related to crabs and shrimp than to insects. And, if you'll allow a bit more pedantry, 'bug' technically refers to certain insects with sucking mouthparts.

The newly described isopod is different from most of its kin, however. The blind, colourless crustacean, which is less than one-centimetre (0.4-inches) long, is aquatic, scraping out a living in cave ponds.

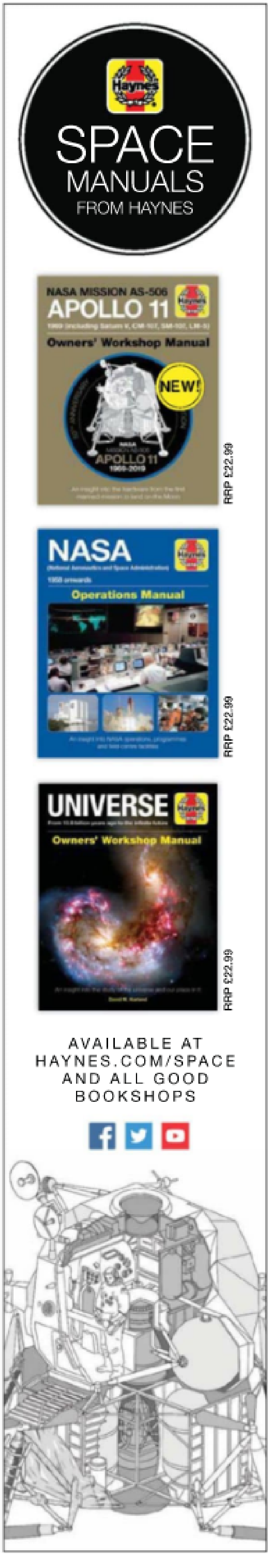
It was first found during the 2012 edition of CAVES (Cooperative Adventure for Valuing and Exercising human behaviour and performance Skills), a two-week European Space Agency training course held in Sardinia's Sa Grutta cave system. The experience is designed to help astronauts learn to work together in a space-like environment.

CAVES also involves a variety of other research activities, as the isopod discovery shows. Astronauts from Europe, the United States, Canada, Russia, Japan and China helped collect and describe the little crustacean in 2012 and on subsequent CAVES expeditions. The astronauts' aid is reflected in the little beast's scientific name, Alpioniscus sideralis – 'sideralis' is from the Latin word for star.

"I would like to think that when humans land on Mars and explore its caves, this experience will help them to look for other species knowing that life has few limits and can develop in the most inhospitable places," Paolo Marcia, a zoologist from the University of Sassari in Italy who heads the CAVES biology experiments, said in a statement.



The newfound creature is related to terrestrial isopods



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Starquakes rock alien sun, revealing details of a 'hot Saturn'

Words by **Rafi Letzter**

NASA space observatory TESS has, for the first time, detected a planet orbiting a star with visible starquakes.

TESS, launched in April 2018, is just beginning to show scientists what it can do. Like its predecessor, the Kepler space telescope, the orbiting TESS detects planets by watching the brightness of their host stars dip as the planets pass between the stars and the telescope. Unlike Kepler, the TESS satellite focuses on a group of bright stars relatively close to Earth and spread across a wide span of the sky. TESS can also detect starquakes – seismic waves that pass through stars like earthquakes travel through Earth – by watching more rapid changes in those same stars' brightness.

Starquakes rock every star to some degree, but they're not always detectable. When astroseismologists can spot this phenomenon, though, the stellar shaking offers useful information about a star's mass, age and size. In turn, that information can help astronomers figure out details about the planets orbiting those stars.

TESS data has revealed that host star TOI-197 is 5 billion years old and a bit bulkier than our Sun – and, critically, just beginning to transition into a red giant. The planet orbiting this star, TOI-197.01, is a gas giant about the size of Saturn, but orbits so close to its star that its entire orbit takes just 14 days.

TOI-197.01, orbiting so close to its star, gets cooked by the burgeoning red giant. The astronomers suggested that, as the star expands, the planet might puff up from the heat to an even larger size, joining a class of large, low-density gas giants orbiting red giants that Kepler discovered.

Ready for the Red Planet: NASA's Mars Helicopter aces key flight tests

Words by **Mike Wall**

NASA's Mars Helicopter has proven its off-world mettle. The technology demonstrator, which will launch with NASA's next Mars rover in July 2020, aced its first-ever test flight under Red Planet conditions, agency officials have announced.

"Gearing up for that first flight on Mars, we have logged over 75 minutes of flying time with an engineering model, which was a close approximation of our helicopter," Mars Helicopter project manager MiMi Aung of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, said in a statement. "But this recent test of the flight model was the real deal," she added. "This is our helicopter bound for Mars. We needed to see that it worked as advertised."

The test took place in January in the Space Simulator, a vacuum chamber at JPL that has helped prep many robotic planetary explorers over the decades. Aung and her colleagues configured the chamber to mimic the wispy, carbon-dioxide-dominated Martian atmosphere, which is just one percent as thick as that of Earth.

The team also outfitted the helicopter with a 'gravity offload system' – a motorised lanyard that pulled upward on the craft continuously so that it experienced Mars gravity during flight. The gravitational pull on Mars' surface is just 40 per cent as strong as Earth's.

The helicopter aced its first-ever test flight under alien conditions

"The gravity offload system performed perfectly, just like our helicopter," Mars Helicopter test conductor Teddy Tzanetos, also of JPL, said. "We only required a two-inch [5 centimetre] hover to obtain all the datasets needed to confirm that our Mars helicopter flies autonomously as designed in a thin, Mars-like atmosphere; there was no need to go higher. It was a heck of a first flight."

Weirdly coloured Saturn moons linked to ring features, NASA's Cassini revealed

Words by **Charles Q. Choi**

The bizarre shapes and diverse colours seen in some of Saturn's moons may now be explained with the help of data taken by NASA's Cassini spacecraft before it plunged to its doom.

These moons likely coalesced from the planet's rings, and get their colour from either ice volcanoes or a mysterious red material in the rings, according to a new study.

Saturn not only possesses extraordinary rings, but also more than 60 moons. A half-dozen or so of these moons appear linked with the giant planet's main rings, either lodged within these features or gravitationally interacting with them to sculpt their shapes and influence their composition.

The ring moons often possess bizarre features; for example, Pan and Atlas are shaped like flying saucers. Saturn's moons can also vary in colour from adjacent rings, and astronomers have questioned why these differences appear.

The relationship between the planet's rings and these moons suggests that the rings' and moons' origins and continued existence are linked, researchers have said. Previous work suggested either that the moons coalesced from ring material or that the rings formed from the disintegration of a moon.

Saturn possesses over 60 natural satellites around it

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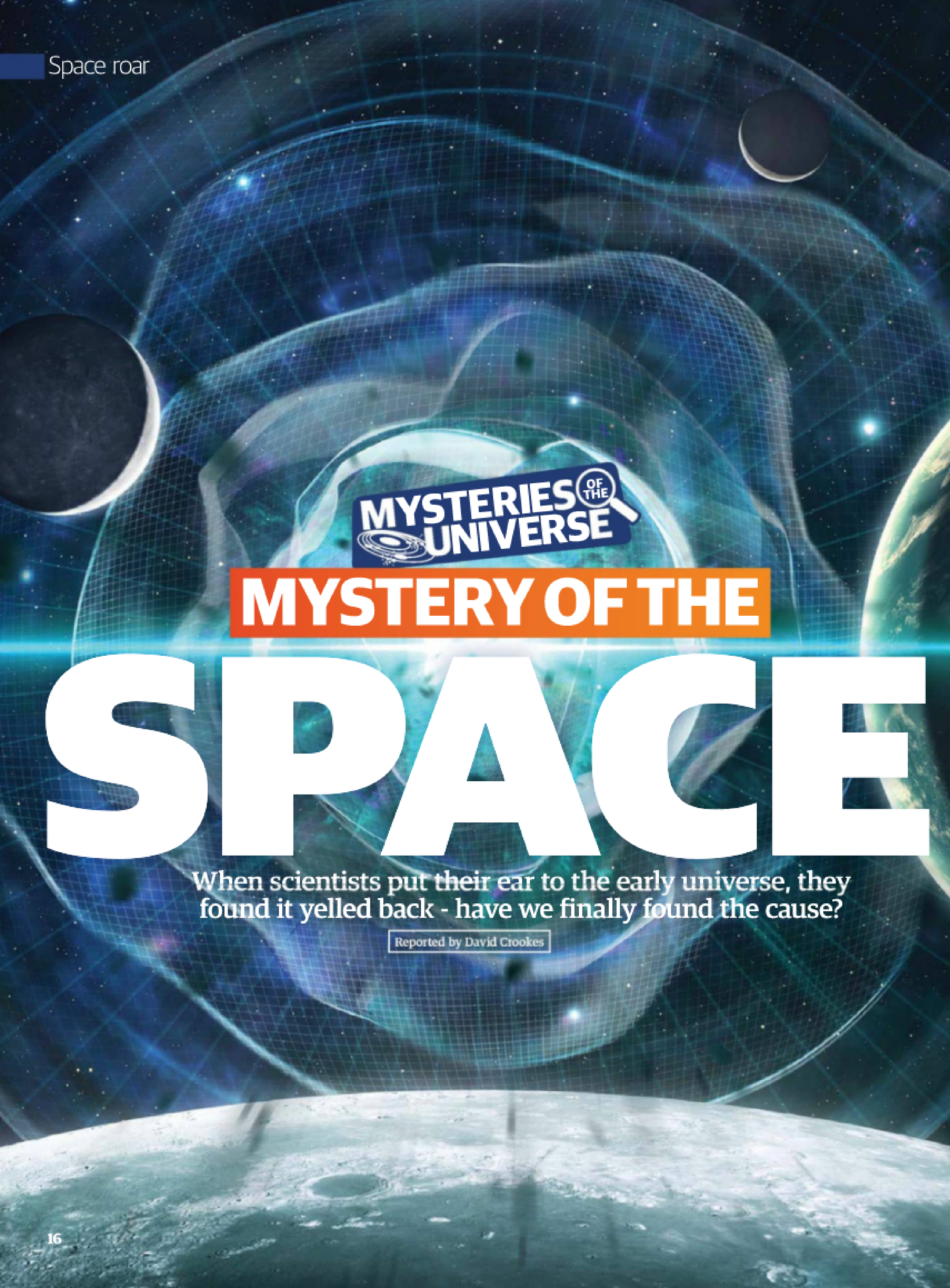


MYSTERIES OF THE UNIVERSE

MYSTERY OF THE SPACE

When scientists put their ear to the early universe, they found it yelled back - have we finally found the cause?

Reported by David Crookes

ROAR

In space nobody can hear you scream but, with the right equipment, it is possible to detect a roar. Indeed, that's what scientists discovered back in 2006 when they began to look to the dawn of the universe using seven precision radiometers fixed to a machine that was sent to space on a huge balloon. It was able to pick up radio waves from the heat of distant stars, but what came through that year was nothing short of astounding.

As the machine listened from a height of about 37 kilometres (23 miles), it picked up a signal that was six-times greater than expected by cosmologists. Too loud to be early stars and far greater than the predicted combined radio emission from distant galaxies, it caused great puzzlement. Yet scientists still don't know what is causing it. What's more, it could even hamper efforts to search for signals from the first stars to form after the Big Bang.

To understand what's going on, it's important to establish some facts. First of all, the instrument that was sent into space that year was the Absolute Radiometer for Cosmology, Astrophysics, and Diffuse Emission (ARCADE), and it was built to extend the study of the cosmic microwave background spectrum at lower frequencies.

Its science goals - as it floated high above Earth's atmosphere, free of interference from our planet - were to find heat from the first generation of stars, search for particle physics relics from the Big Bang and observe the formation of structure from the first stars and galaxies. It did so by scanning seven per cent of the night sky looking for radio signals, since distant light becomes radio waves as it loses energy over distance.

In this sense ARCADE was able to make 'absolutely calibrated zero-level' measurements, which means it was measuring the actual brightness of something in real physical terms rather than whether an object was brighter relative to another. This was different to typical radio telescopes which observe and contrast two points in the sky. By looking at all of the 'light' and comparing it to a blackbody source, ARCADE was able to see the combination of many dim sources. It was then the intensity of one particular signal became apparent, albeit over many months.

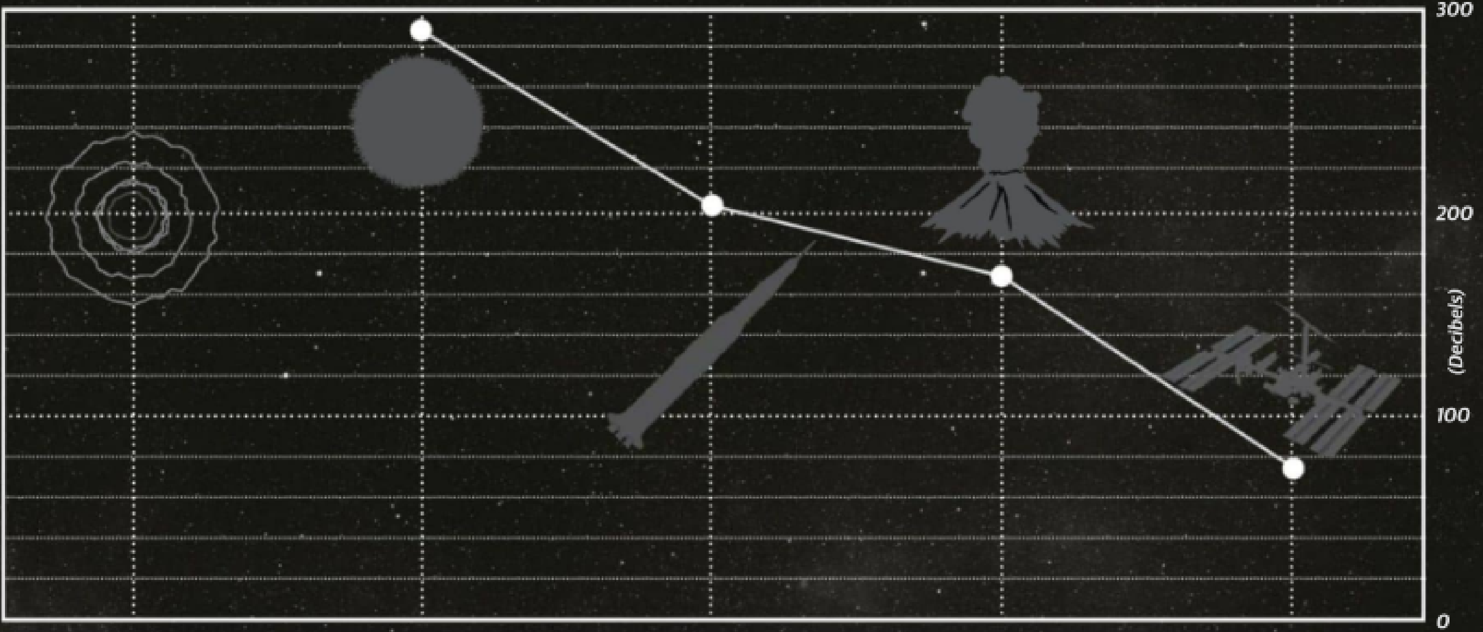
"While it might make a good movie to see us surprised when we see the light meter pop over to a value six-times what was expected, we actually spent years getting ready for our balloon flight and a very busy night taking data," says NASA scientist Dale J. Fixsen. "It then took months of data analysis to first separate instrumental effects from the signal and then to separate galactic radiation from the signal. So the surprise was gradually revealed over months." That said, the impact was still huge.

Since then scientists have looked to see where the radiation is coming from while looking to establish the properties of the signal. The latter

The space roar is caused by synchrotron radiation which is created when atomic particles spiral around magnetic field lines

Sound comparisons in the universe

Listen up: space could be a noisy place if it was full of air



Space roar
Six-times intensity of any source measured
The space roar has been found to be much louder than most parts of the universe.

The Sun
290 decibels
If we could hear the Sun, we'd all be wearing earmuffs. Even from Earth the Sun would be 125 decibels.

Saturn V rocket
204 decibels
If you were standing too close when a rocket launched, the constant sound would seriously hurt your ears.

A big caldera
172 decibels
Krakatau made an incredible sound when it erupted on 27 August 1883; it was heard 100 miles away.

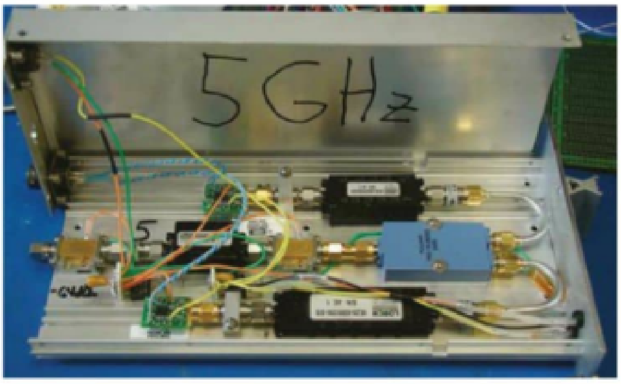
ISS
78 decibels
ISS astronauts used to wear earplugs all day, but NASA worked on lowering noise levels.

became apparent rather quickly. "It's a diffuse signal coming from all directions, so it is not caused by any one single object," explains Al Kogut, who headed the ARCADE team at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "The signal also has a frequency spectrum, or 'colour', that is similar to radio emission from our own Milky Way galaxy."

Scientists call the signal 'radio synchrotron background' - background being an emission from many individual sources and blending together into a diffuse glow. But because the 'space roar' is caused by synchrotron radiation, a type of emission from high-energy charged particles in magnetic fields, and since every source has the same characteristic spectrum, pinpointing the origin of this intense signal is difficult.

"It has been known since the late-1960s that the combined radio emission from distant galaxies should form a diffuse radio background coming from all directions," explains Kogut. "The space roar is similar to this expected signal, but there doesn't seem to be six-times more galaxies in the distant universe to make up the difference, which could point to something new and exciting as the source."

Whether or not this source is inside or outside the Milky Way has been debated. "There are good arguments why it cannot be coming from within the Milky Way galaxy, and good arguments for



Above: This is the 5 GHz radiometer back end, which splits into two frequency subchannels

Left: Getting ready for the launch of the ARCADE module, which peered back to the dawn of the universe

What do the results say?

What scientists know about the mysterious roar

"If it is from a halo around our galaxy, it would make the Milky Way a weird galaxy"

NASA's Dale J. Fixsen says the Milky Way looks like a normal spiral galaxy, so it would be unusual if the roar was found to come from a source connected with it.

"The determination of the level of the radio background was not solely based on ARCADE"

Jack Singal, assistant professor of physics at the University of Richmond, says other measurements at lower frequencies have previously hinted at such radio background, going back to the 1960s.

"Current data shows the problem, but doesn't really point to a solution"

Al Kogut, who headed the ARCADE team, says projects such as the 91-metre (300-foot) radio telescope at Green Bank will help resolve the issue.

why it cannot be coming from outside the galaxy," Kogut tells us. One of those which falls into the former is that it doesn't seem to follow the spatial distribution of Milky Way radio emission, but nobody is saying for certain that it isn't from a source closer to home, only that the smart money is on it coming from elsewhere.

"I wouldn't quite say that scientists have largely ruled out the possibility of the radio synchrotron background originating from our galaxy," says Jack Singal, assistant professor of physics at the University of Richmond, who recently led a workshop on the matter. "However I would say that this explanation does seem to be less likely.

"The primary reason is that it would make our galaxy completely unlike any similar spiral galaxy, which as far as we can tell do not exhibit the sort of giant, spherical, radio-emitting halo extending far beyond the galactic disc that would be required. There are other issues as well, such as that it would require a complete rethinking of our models of the galactic magnetic field."

Fixsen agrees wholeheartedly with this. "In other spiral galaxies there is a close relation between the infrared and radio emission, even in small sections of these others. So if it is from a halo around our galaxy it would make the Milky Way a weird galaxy, while in most other respects it seems like a 'normal' spiral galaxy," he tells us.

This would by default point to an excess signal that is primarily extragalactic in origin. "It would make it the most interesting photon background in the sky at the moment because the source population is completely unknown," Singal says. But since the universe is so vast this doesn't exactly narrow things down that much, which is why scientists have been working hard to come up with multiple theories.

Some ideas are hard to get your head around. American physicist David Brown, for example, says the space roar could be "the first great empirical success of M-theory", a broad mathematical framework encompassing string theory. "There might be a Fredkin-Wolfram automaton spread across multitudes of alternate universes, yielding recurrent physical time with endless repetitions of all possible physical events," he wrote on a blog. What this supposes is the early universe had much more real matter than today, accounting for the powerful radio signal.

But if that is too far out, then there are other theories to get your teeth into. "Radio astronomers have looked at the sky and have identified a couple of types of synchrotron sources," Fixsen says. "These have distributions that can be extrapolated so we can account for the full distributions."

He explains that synchrotron radiation is easy to make. "All you need is energetic particles and a magnetic field, and there are energetic particles everywhere, produced by supernovae, stellar winds, black holes, even OB stars," he says. "Intergalactic

"What this supposes is the early universe had much more real matter than today, accounting for the powerful radio signal"

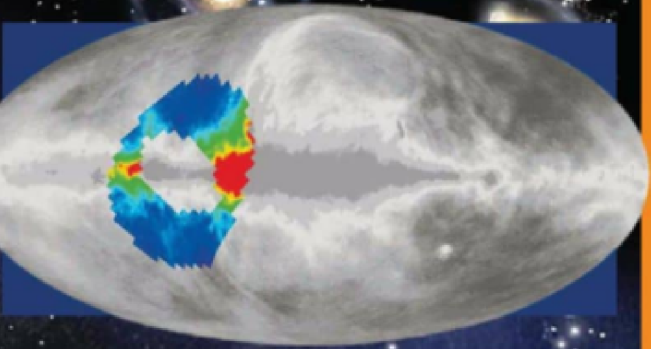
Above: Jack Singal, assistant professor of physics at the University of Richmond, tapes down heaters on ARCADE 2

Below: The giant balloon is being filled prior to its launch, and stands upright

© NASA; Adrian Mann

ARCADE

How a balloon was able to detect the space roar

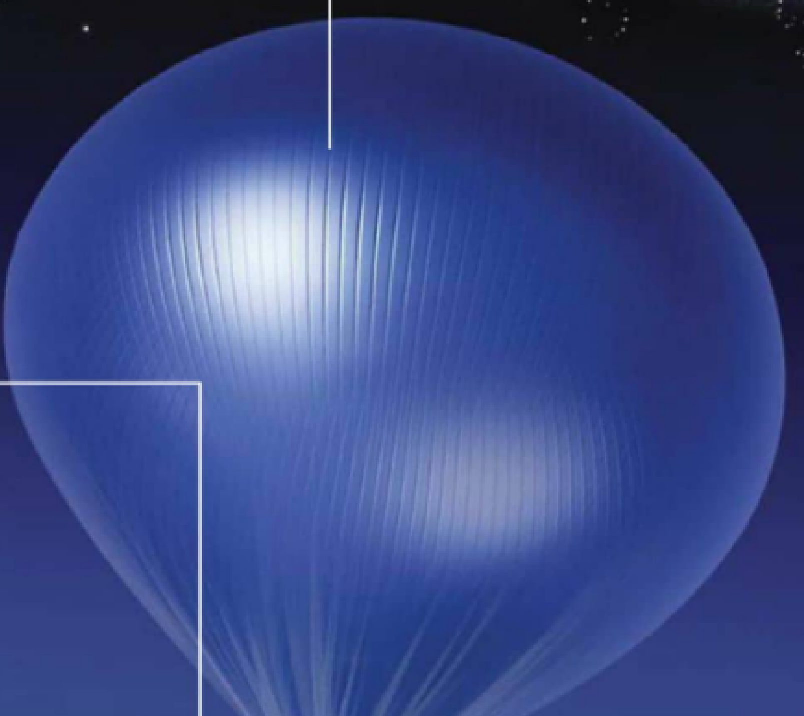


The balloon

This giant helium balloon was tethered to ARCADE, allowing the payload to be carried to an altitude of 37 kilometres (23 miles), from where it had an unobstructed view into space.

Seven radiometers

Soaked in liquid helium, the seven radiometers were placed towards the top of the vacuum flask. They measured the frequency spectrum of the Cosmic Microwave Background at centimetre wavelengths.

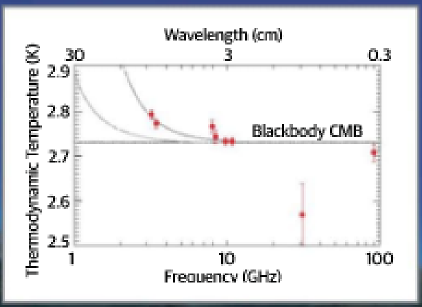


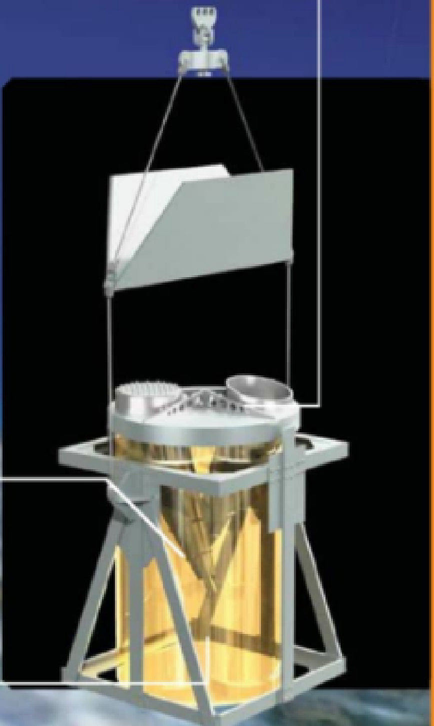
Reflective shield

The reflective shield which sat above the vacuum flask ensured the antennae did not have a view of the flight train and the parachute.

Sky-observing aperture

The carousel had a porthole for sky viewing. During its observations ARCADE was able to view about seven per cent of the night sky.





The antennae

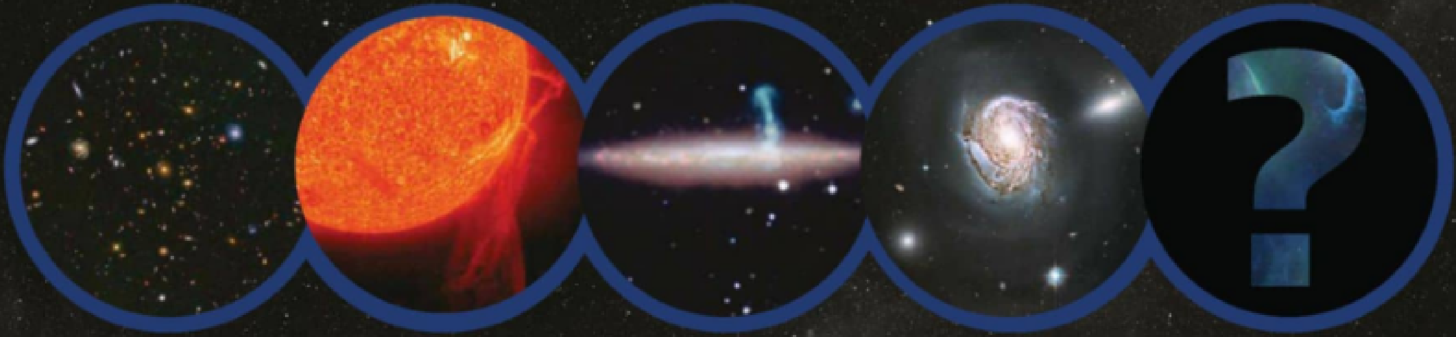
Each of the corrugated horn antennae picked up a different frequency band, observing at 3, 5, 8, 10, 30, 30 and 90 GHz. One of the 30 GHz antennae had a narrower antenna beam for cross checking.

Liquid helium

Since the instruments needed to measure tiny differences in temperature from the very first stars, it was important that ARCADE was as cool as possible. Liquid helium cooled the payload to -270°C (-454°F).

What it's thought to be

Numerous theories about the space roar have been raised



The earliest stars

ARCADE was designed to detect the faintest signs of heat from the first generation of stars, so do these account for the noise? It's unlikely since it was six-times louder than expected – far greater than what those stars should be emitting.

A bubble around the Sun

It's possible that there is a small bubble around the Sun. As scientist Dale J. Fixsen tells us, it wouldn't have to be very bright since it is so close to us, thereby appearing normal.

Dim radio galaxies packed together

There is one major problem with the theory that the source is radio galaxies very close together: those galaxies would have to be so packed that they'd effectively merge into one.

Gases swirling around galaxy clusters

Maybe radiation is being emitted from the gases of large galaxy clusters, but the main issue here is that the instruments used by ARCADE are unlikely to have picked them up.

An unknown source

The most likely explanation is that there is something out there that we just haven't yet discovered, and that is why the 'space roar' is so exciting. The only way we'll discover the root cause is with further investigation.

Above left: Was there more real matter in the very early universe, accounting for a louder noise when seeking to monitor those fledgling moments?

Left: NASA scientist Dale J. Fixsen (right) works with Ed Wollack (left)

NASA; JPL-Caltech; ESO.

space seems to be filled with very hot gas, so if intergalactic magnetic fields were strong enough [stronger than predicted], they could generate smooth synchrotron radiation."

It is also known that synchrotron radiation is associated with star production. "This also generates infrared radiation, hence the close correlation," Fixsen continues. "But perhaps the first stars generated synchrotron radiation yet, before metals were produced, they did not generate very much infrared radiation. Or perhaps there is some process that we haven't thought of yet."

So what does this leave us with? "Possible sources include either diffuse large-scale mechanisms such as turbulently merging clusters of galaxies, or an entirely new class of heretofore unknown incredibly numerous individual sources of radio emission in the universe," Singal tells us. "But anything in that regard is highly speculative at the moment, and some suggestions that have been raised include annihilating dark matter, supernovae of the first generations of stars and many others."

Indeed, some scientists have suggested gases in large clusters of galaxies could be the source, although it's unlikely ARCADE's instruments would have been able to detect radiation from any of them. Similarly, there is a chance that the signal was detected from the earliest stars or that it is originating from lots of otherwise dim radio galaxies, the accumulative effect of which is being picked up. But if this was the case then they'd have to be packed incredibly tightly, to the point that there is no gap between them. In reality this appears unlikely.

"Of course there is also the possibility that there has been a coincidence of errors among ARCADE and the other measurements to date that have mismeasured the level of the radio synchrotron background," says Singal. "This does seem unlikely given that these are very different instruments measuring in quite different frequency bands."

Whatever the signal is, it's also causing a knock-on effect. As NASA has pointed out in the past, the earliest stars are hidden behind the space roar, and that is making them more difficult to detect. It is as if science is giving with one hand and taking with another, but to have uncovered something so unusual is immensely exciting. When you're ruling out an origin from primordial stars and known radio sources such as gas in the outermost

> "I think we may need some brilliant new origin hypothesis that nobody has thought of yet" **Dr Jack Singal**

halo of our galaxy, it's a mystery any scientist would savour with relish.

In order for scientists to finally resolve this 13-year conundrum, more research and evidence is sorely needed. As it stands there is a debate over sending ARCADE back up, and given its precise set of instruments, immersed in more than 500 gallons of ultra-cold liquid helium to make them even more sensitive, there would certainly be no harm in doing so.

But there are also new projects emerging which could help. "One of them will use the 91-metre (300-foot) radio telescope at Green Bank, West Virginia, to map the radio sky to higher precision than before," says Kogut. "Perhaps this will shed some light on the mystery."

Singal certainly hopes so. He is working on the Green Bank Telescope project, making use of the largest clear-aperture radio telescope in the world to measure the level of the background as a primary, rather than ancillary goal. It will do this using a definitive, purpose-built, absolutely calibrated zero-level measurement taken at the MHz frequencies where the radio sky is brightest.

"This measurement is currently being developed by a team which I am on, utilising custom instrumentation which will be mounted on the telescope," he tells us. There is also going to be another measurement attempt, this one looking to measure or further limit the so-called 'anisotropy' of the radio synchrotron background, again at the MHz frequencies where it dominates.

"That is not its absolute level, but rather the small differences from place to place in the sky," Singal says. "With some collaborators I am trying a first attempt at that using the Low-Frequency Array [LOFAR] in The Netherlands. Both of these measurements in concert can help nail down whether the radio synchrotron background is primarily galactic or extragalactic in origin. Beyond that, I think we may need some brilliant new origin hypothesis that nobody has thought of yet."

Above: Such is the 'noise' from the space roar, astronomers fear not being able to monitor the earliest of stars following the Big Bang

Right: ARCADE was launched on a large balloon in 2006

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The ESA, along with one of its astronauts, Tim Peake, has devised a series of tests to see if there are any astronaut candidates hidden among the public

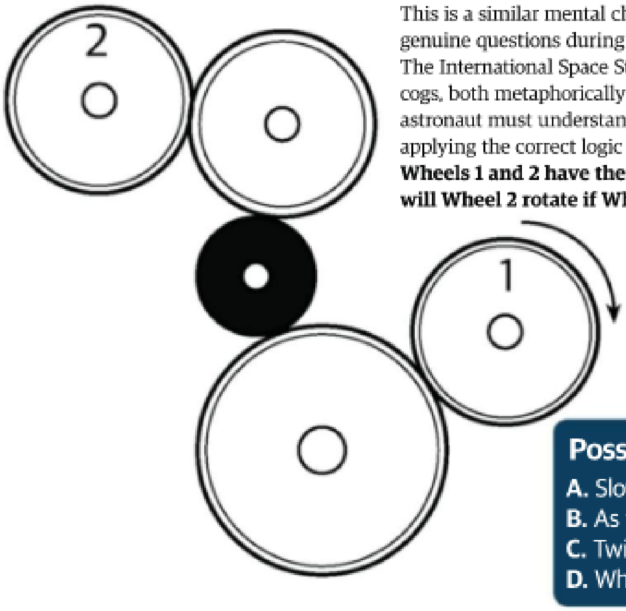
SOLVE TIM PEAKE'S ASTRONAUT SELECTION TEASERS

Astronauts must undergo an intense period of examination if they are to ever leave Earth for the zero-gravity of space. As the old saying goes, nothing comes easy! In order to give people a peak behind the curtain, the European Space Agency and its most esteemed UK-born astronaut, Tim Peake, have put together a book that showcases part of what is needed to be an astronaut: *The Astronaut Selection Test Book*.

There are also lots of physical examinations in order to determine if one's body can handle the harsh and unusual environment of space, the main culprits being the effects of microgravity and g-force on launch and descent. But the mind is just as important as the body, and astronauts must be able to problem solve on a moment's notice - it could be the difference between life and death.

Some of the tests that astronauts need to undertake examine their spatial awareness, pattern recognition, mental arithmetic abilities and the skill to learn different languages. Here are some variants of the tests and riddles that are in Tim Peake's test book, to give a taster into the training for an astronaut. So, only one question remains… do you have what it takes? Spoiler alert: the answers can be found on page 29.

1 WHEELS KEEP ON TURNING

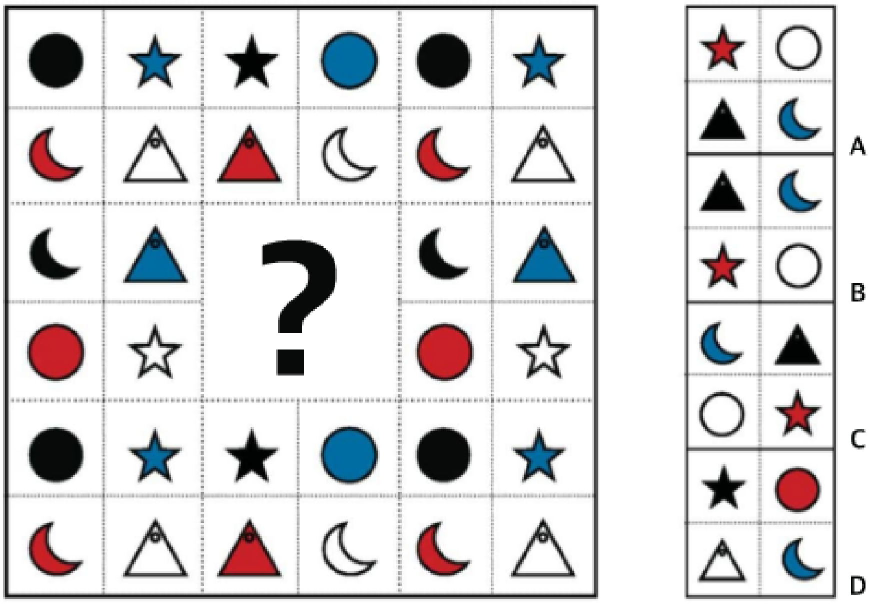


This is a similar mental challenge to one of the genuine questions during the ESA selection process. The International Space Station is full of turning cogs, both metaphorically and quite literally, so an astronaut must understand how they operate by applying the correct logic to the situation. **Wheels 1 and 2 have the same radius. How fast will Wheel 2 rotate if Wheel 1 is being driven?**

Possible answers

A. Slower than Wheel 1
B. As fast as Wheel 1
C. Twice as fast as Wheel 1
D. Wheel 2 does not rotate

"ASTRONAUTS MUST BE ABLE TO PROBLEM SOLVE ON A MOMENT'S NOTICE - IT COULD BE THE DIFFERENCE BETWEEN LIFE AND DEATH"

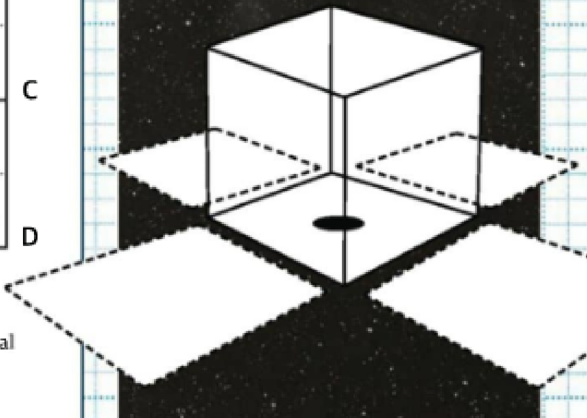


2 PATTERN RECOGNITION

Deciphering complex patterns is an important part of being an astronaut. This helps pull critical information from a bad situation and can prove to be vital while in space. **In order to complete this puzzle, you must identify the pattern and determine the missing tile.**

3 SPATIAL AWARENESS

Astronauts have little room to manoeuvre and operate. This means they must be aware of their surroundings and how they can operate equipment carefully in microgravity, especially on a spacewalk. Imagine that you are facing this cube. This cube can roll left, right, forward (towards you) and backwards (away from you). **Before any rolls have occurred, a dot sits at the bottom of the cube. Now imagine you've rolled the cube forward, left, right, right, forward, left, backwards and right. Where is the dot?**



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4 MENTAL ARITHMETIC

Maths is a subject dreaded by many people, but you can't get near a spacecraft if you don't understand this numerical language. Maths is essential in order to complete tasks and understand the station.

A passenger at London Heathrow wants to get from Terminal 1 to Terminal 2. On foot it would take them three minutes, and standing still on a conveyor belt would take only two minutes. How much time would it take them if they walked on the conveyor belt?

Possible answers

- **A.** Two minutes
- **B.** One minute
- **C.** 1.2 minutes
- **D.** 1.5 minutes

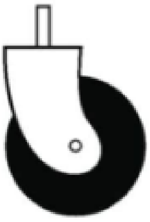
5 SWIVEL CHAIRS

Another spatial awareness test involves the wheel of a swivel chair. This is designed to identify the wheel that can provide the maximum amount of efficiency when parking equipment, again while operating in minimum space.

Which is the most useful swivel-chair wheel?

Possible answers

- **A.** 3
- **B.** 1
- **C.** None
- **D.** 2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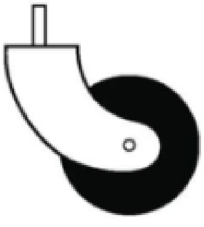
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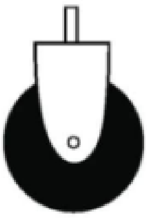
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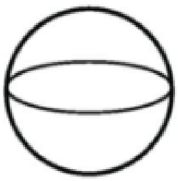
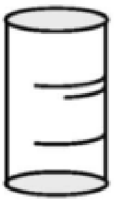
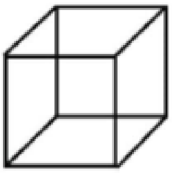
6 UNDERSTANDING SHAPES IN 3D

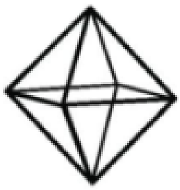
Understanding shapes in 3D shows the ESA who has good visual perception. This allows astronauts to manipulate equipment and tools in an effective and correct way.

A line runs through the centre of one of these shapes that is equidistant from all surfaces. Select the shape where this is possible.


A sphere


A cylinder
(with no ends)


A cube

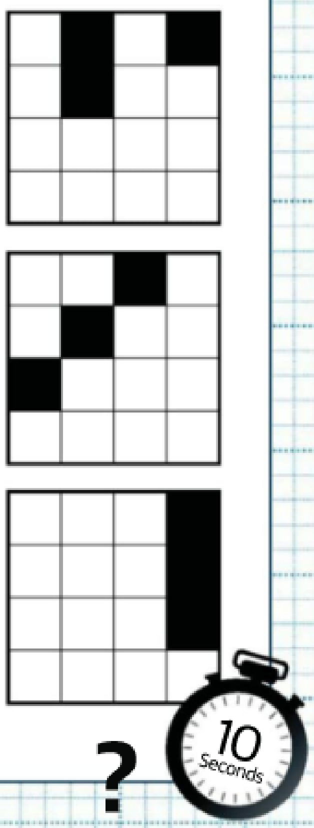

An octahedron

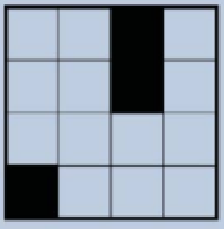
> "UNDERSTANDING SHAPES IN 3D SHOWS THE ESA WHO HAS GOOD VISUAL PERCEPTION"

7 TIMED PATTERN RECOGNITION

It's time to step it up a bit – you never know when you're going to be put on a timer. This will definitely determine if you can perform a cognitive task while under pressure.

You're only allowed ten seconds to answer this one: Which square should follow the sequence, starting from the top square and going downward?

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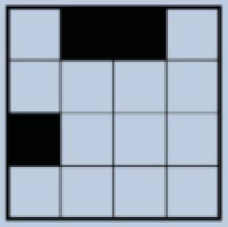
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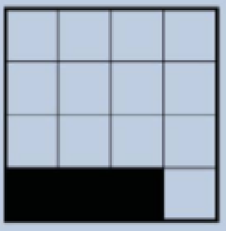
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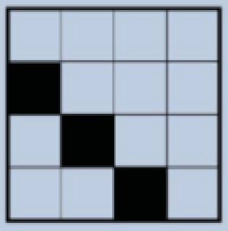
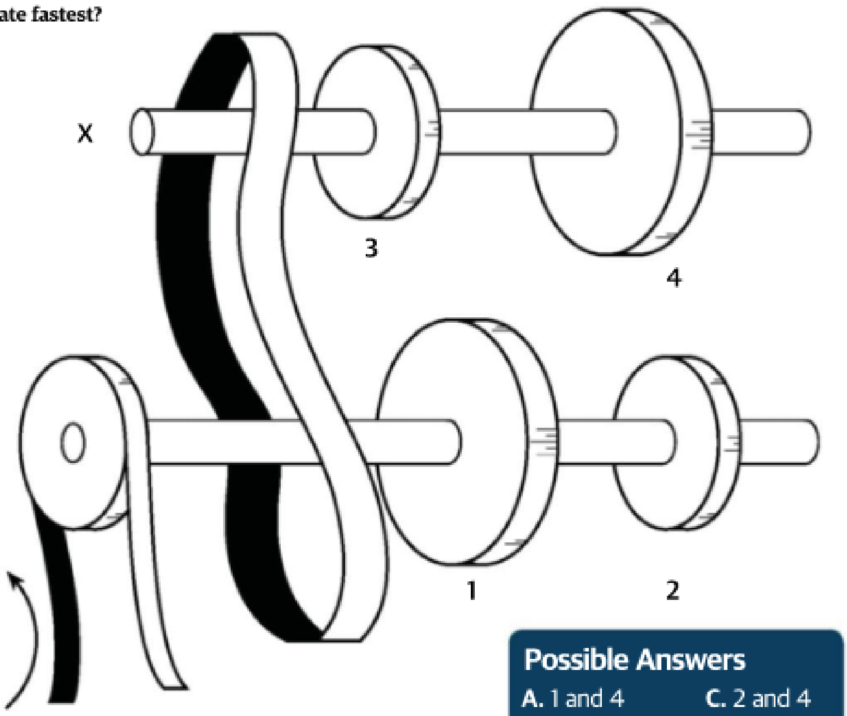

D

8 WHEELS AND BELTS

Another test of visual perception in order to demonstrate tool manipulation. This question is the astronautic version of 'what happens if the chain detaches from the gears?'.

Across which of the wheels does the drive belt have to be tightened for the top axis 'X' to rotate fastest?



Possible Answers

A. 1 and 4
B. 2 and 3
C. 2 and 4
D. 1 and 3

9 UNDERSTANDING DIFFERENT LANGUAGES

Russian is the other official language (other than English) of the International Space Station so astronauts undergo intensive Russian lessons before they are even allowed into space. This is important because the Soyuz spacecraft's controls are in Russian.

Using the following translation chart, translate the following space-related words written in Russian into English.

Аа - a as in father
Бб - b as in but
Вв - v as in van
Гг - g as in get
Дд - d as in dress
Ее - ye as in yesterday
Ёё - yo as in yonder
Жж - zh as in measure
Зз - z as in zoo
Ии - ee as in meet
Йй - y as in toy
Кк - k as in class
Лл - l as in love
Мм - m as in mother
Нн - n as in name
Оо - o as in bottle
Пп - p as in paper
Рр - r as in error
Сс - s as in smile
Тт - t as in ten
Уу - u as in cool
Фф - f as in farm
Хх - h as in loch
Цц - ts as in its
Чч - ch as in chess
Шш - sh as in fish
Щщ - shch as in fresh chat
Ъъ - 'hard sign'
Ыы - i as in bill
Ьь - 'soft sign'
Ээ - e as in bet
Юю - yu as in Yugoslavia
Яя - ya as in yard

модуль

....

спутник

....

станция

....

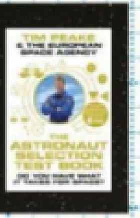
ракета

....

телескоп

....

For more tests, brainteasers and to learn more about astronaut training, Tim Peake and the ESA's *The Astronaut Selection Test Book: Do You Have What it Takes for Space?* is available to purchase now.



Answers 1. B **2.** B **3.** Top **4.** C **5.** D **6.** A cylinder **7.** D **8.** D **9.** Module, Sputnik, Station, Rocket, Telescope

© NASA, ESA

WHY WATER ISN'T KEY TO LIFE

A new picture of our galaxy filled with exotic oceans and alien seas has raised questions about our focus on H_2O in the search for life

Reported by James Romero

"If there is magic on this planet it is contained in water," observed Loren Eiseley, the great natural science writer, as he watched a beetle from his window bathing inside an algae-filled rooftop puddle. Where there is water, invariably there is life - on Earth at least. But what about other worlds? How far does this reliance on water extend out into the cosmos?

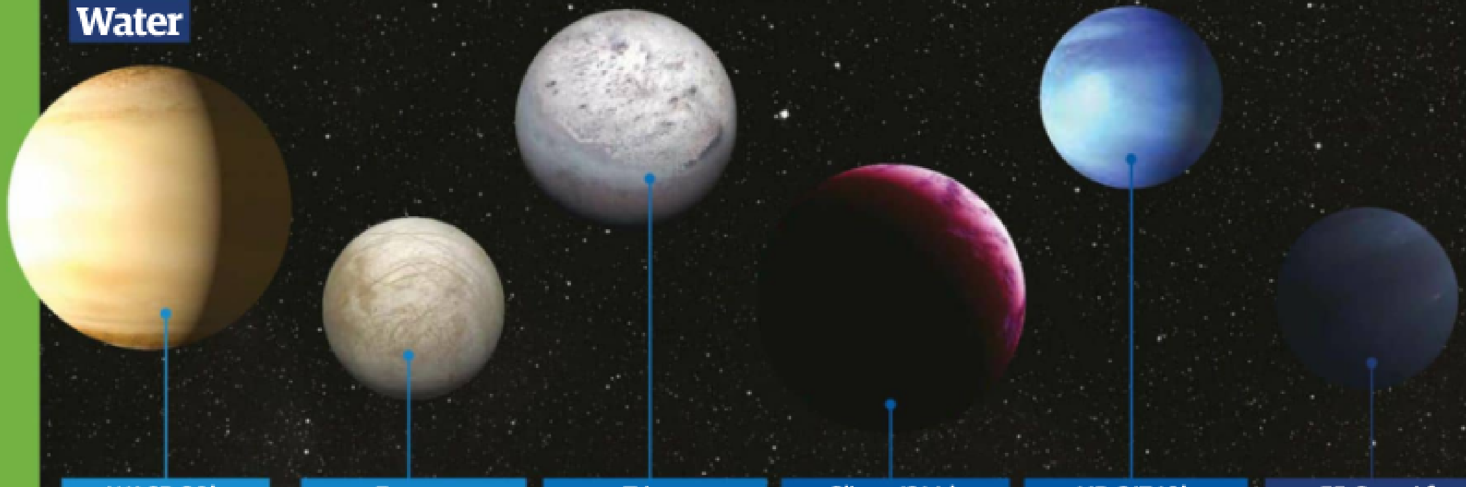
These questions come into focus with new evidence that Earth's water oceans might be relatively rare on galactic scales, where a wide variety of exotic and alien seas dominate. The team behind the research claims their results cast doubt on a founding principle in the search for alien life over the past half a century: following the water.

Are we being too narrow in our search for life forms among the stars? Are we searching for the life we know rather than what might be out there because of an overemphasis on our own genesis story? Alternatively, are we right to place water on an astrobiological pedestal as the ultimate medium

Water and organics: exoplanet families

The simple chemistry of H_2O and organic molecules makes them ubiquitous in gas, liquid and ice across the Solar System and cosmos

Water



WASP-39b
This 'hot Saturn' contains large quantities of water in its atmosphere, possibly from its formation further out.

Europa
Jupiter's moon has a water-ice surface. However, it is the deep ocean we think lies beneath that excites astrobiologists most.

Triton
Recent modelling suggests that tidal heating from Neptune could help maintain a subsurface 'liquid layer' under its water-ice crust.

Gliese 1214 b
Discovered in 2009, this super-Earth has been dubbed 'the waterworld' and is the most likely ocean exoplanet candidate.

HD 21749b
A sub-Neptune exoplanet too dense to be a gas giant, but not dense enough to be rocky. It sits closer to the density of water.

55 Cancri f
An ice giant with no solid surface. It orbits in the habitable zone, which means liquid water could exist on the surface of any moon.

for creation? And if not an unrivalled prerequisite for life, is liquid still the most likely?

To answer any of this, we must first address our thirst for oceans more generally when looking for extraterrestrials. "Biologists expect life, similar to what we like to call life, to happen in a solution," says Alberto Fernandez-Soto, an astronomer at Instituto de Fisica de Cantabria in Spain, and one of the authors behind the new study.

Liquids, with their high mobility, allow individual atoms to mix and react, which with time can turn simple molecules into complex chemistry. And perhaps even animate the inanimate. "Chemical reactions are hopelessly slow in a solid phase, and hopelessly diffuse in the gas phase," says Steve Benner, who co-authored a National Academy of Sciences paper called *Weird Life* with John Baross in 2009 that assessed the essentials for the chemistry of life.

But water is far from the only liquid sloshing around the universe. It isn't even unique in our Solar System, where lakes the size of the Caspian Sea made of ethane and methane orbit around Saturn on its moon Titan. While superficially similar to landscapes you might find on Earth, Titan is a freezing world, and its lakes present a very different prospect for any future human visitors wishing to take a dip. "Hydrocarbon liquids have a density about half that of water, so it would need a lot of effort for a human to stay afloat, assuming you have good gear to protect you from the cold," says Cyril Grima from the University of Texas Institute for Geophysics, who has measured waves moving across their surface.

However, there are more fundamental differences in Titan's hydrocarbon lakes that might make water a better bet for alien life. Firstly, regardless of this latest study, by most measures of universal molecular abundance water is very common in the cosmos. "We even have evidence of water vapour in the atmosphere of exoplanets, though this is not a positive detection of water oceans on the surface," says Fernando Ballesteros of the University of Valencia, the lead author on the new paper. It's also a polar liquid. In chemistry terms this means it is very good at dissolving other polar molecules, which happens to include many organic molecules that make up humans and other life forms.

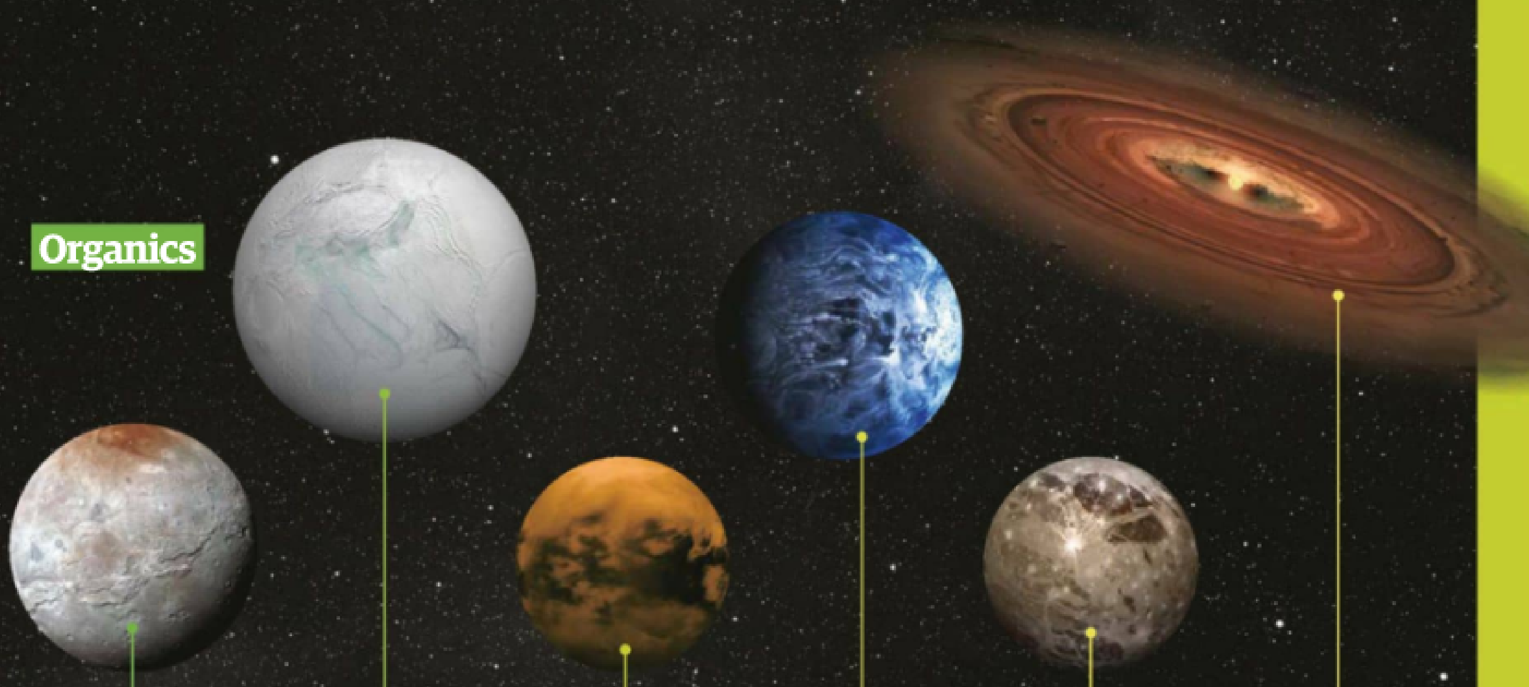
Finally, it remains a liquid at relatively high temperatures. This is a weird feature for chemists, when such small molecules are generally gases at anything approaching room temperature, but one that is critical to astrobiologists because it allows any chemistry to happen faster. And there is a hell of lot of chemistry required to turn inanimate building blocks into life.

Because of these intrinsic properties, the Spanish team understands the strategy of space agencies over the last half century to look for signatures of water both within and outside our own Solar System. "When you have no idea what life is going to look like, you may want to look at things you understand, at least partially. And if you think of life in almost any form on Earth, the inside of their cells is basically liquid water," says Fernandez-Soto.

However, we must avoid the trap of viewing the possibilities of life across the cosmos through

> "When you have no idea what life is going to look like, you may want to look at things you understand" **Alberto Fernandez-Soto**

Organics



Charon
The cap at its north pole is composed of tholins, organic macromolecules produced from gases released from Pluto.

Enceladus
Water vapour containing interesting complex organic molecules spews from this moon's subsurface ocean into orbit around Saturn.

Titan
Saturn's mini frozen Earth is a hazy hydrocarbon world of methane and ethane lakes, rain and rivers.

HD 189733 b
The methane found in its atmosphere represented the first organic molecules detected on a planet outside of our Solar System.

Ganymede
The dark terrain on this Jovian moon, which comprises about one-third of the surface, contains clays and organic materials.

AA Tauri
Its protoplanetary disc contains acetylene and hydrogen cyanide, and it has the potential to form several planets.

what could be a narrow lens of our own origins. The organic molecules that made up the first life on Earth were dissolvable in water. But water was all there was to dissolve in. Perhaps life could form elsewhere using a new set of building blocks 'selected' due to their solubility in a completely different liquid?

The feasibility of other liquids supporting the emergence of life has been considered by many in recent decades. Either side of Benner and Baross' *Weird Life* paper, work from the likes of William Bains and Andrew Stevenson contributed to a body of theories addressing the viability of organic chemistry in hydrocarbon solvents, the possibility of membrane alternatives in non-polar solvents or even the feasibility of complex non-carbon chemistry.

Building on this work, but coming at it from a different angle, Ballesteros and Fernandez-Soto's new paper sought to bring balance to the emphasis on water-born life, not through a hypothetical alternative biochemical process, but through the sheer weight of possibility. They set out to estimate the relative cosmic abundance of various seas in the galaxy in comparison to water ones. Whatever the likelihood of different solutions playing host to their own creation event, the relative abundance of each liquid environment on a galactic scale must surely be a factor in determining the likelihood of discovering it there.

To begin with Ballesteros and Fernandez-Soto, along with colleague Vicent Martinez, engaged with the biology community and decades of literature

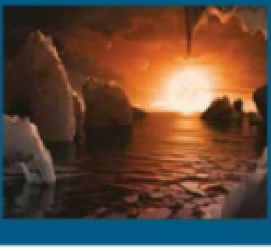
Left: Proxima b is another Goldilocks-zone planet that might be too close to its star to host liquid water

Right: Without water, life as we know it would perish

Too much can be damaging to life

Water worlds might need a bit of land to provide the perfect home for life

Researchers at Arizona State University say there might be too much water sloshing around the TRAPPIST-1 system to harbour life. The planets are up to 50 per cent water by mass, which could press down on the mantle, preventing the volcanism that keeps planets warm. There are also important chemistry of life processes that require dry land.



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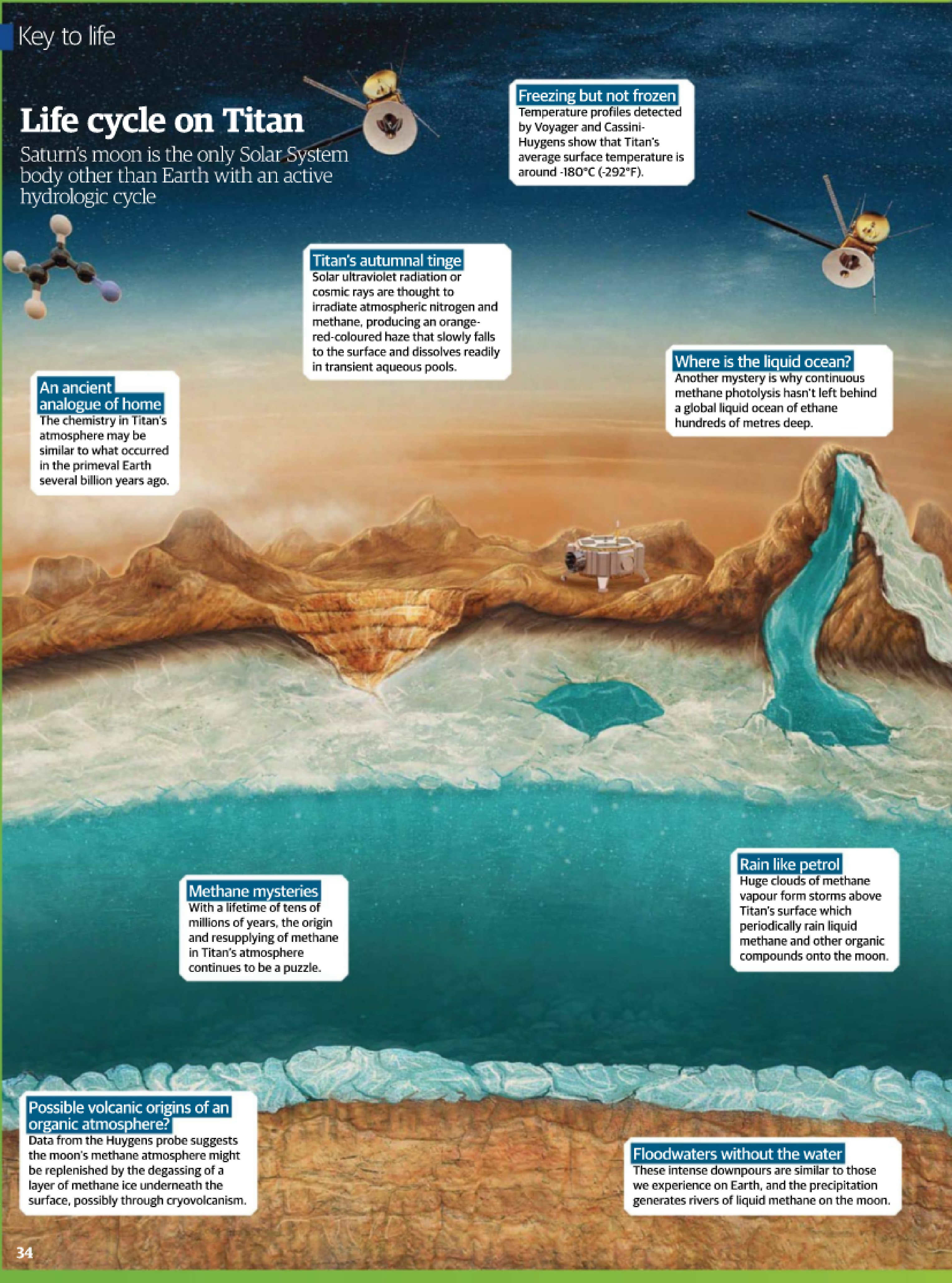
Life cycle on Titan

Saturn's moon is the only Solar System body other than Earth with an active hydrologic cycle



Freezing but not frozen
Temperature profiles detected by Voyager and Cassini-Huygens show that Titan's average surface temperature is around -180°C (-292°F).

Titan's autumnal tinge
Solar ultraviolet radiation or cosmic rays are thought to irradiate atmospheric nitrogen and methane, producing an orange-red-coloured haze that slowly falls to the surface and dissolves readily in transient aqueous pools.

An ancient analogue of home
The chemistry in Titan's atmosphere may be similar to what occurred in the primeval Earth several billion years ago.

Where is the liquid ocean?
Another mystery is why continuous methane photolysis hasn't left behind a global liquid ocean of ethane hundreds of metres deep.

Methane mysteries
With a lifetime of tens of millions of years, the origin and resupplying of methane in Titan's atmosphere continues to be a puzzle.

Rain like petrol
Huge clouds of methane vapour form storms above Titan's surface which periodically rain liquid methane and other organic compounds onto the moon.

Possible volcanic origins of an organic atmosphere?
Data from the Huygens probe suggests the moon's methane atmosphere might be replenished by the degassing of a layer of methane ice underneath the surface, possibly through cryovolcanism.

Floodwaters without the water
These intense downpours are similar to those we experience on Earth, and the precipitation generates rivers of liquid methane on the moon.

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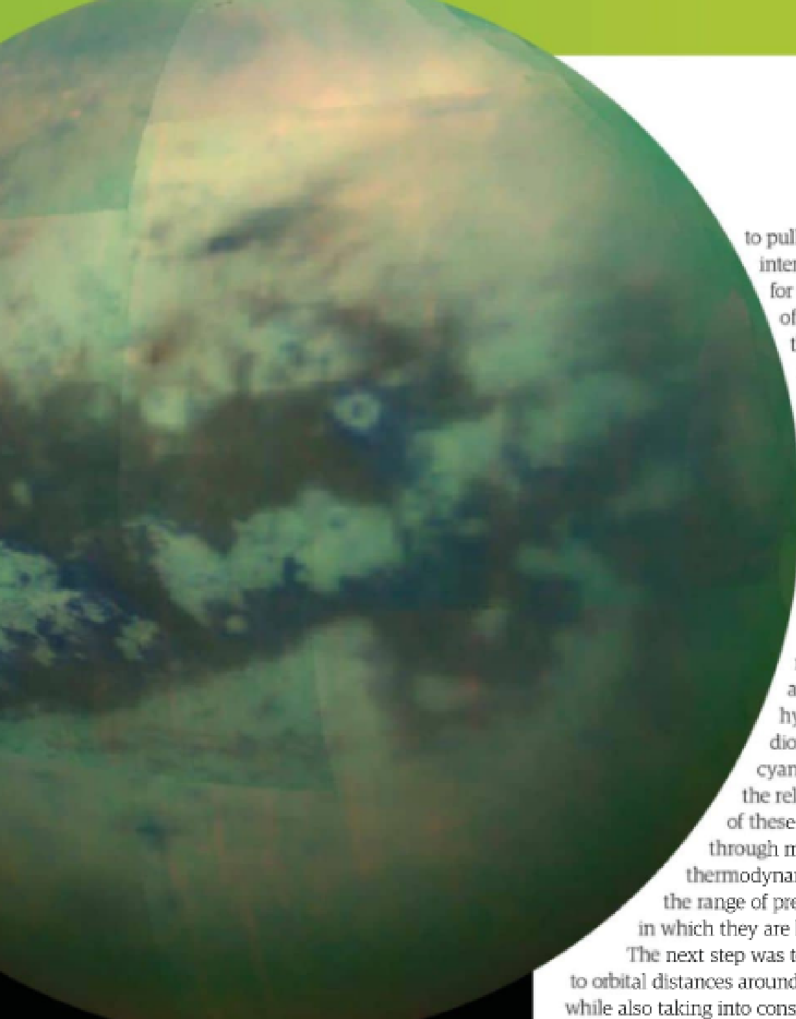


to pull together a fuller list of interesting alternative liquids for the chemical reactions of life. By filtering those that were liquids at realistic temperatures found around stars and composed of the most abundant and common reacting atoms found in spectroscopic analysis of other stellar systems, they ended up with nine candidates. Water, plus methane, ethane, molecular nitrogen, ammonia, sulphuric acid, hydrogen sulphide, carbon dioxide and hydrogen cyanide. They then estimated the relative cosmic abundance of these potential seas through measurements of their thermodynamic properties, such as the range of pressures and temperatures in which they are liquid.

The next step was to map these ranges to orbital distances around every type of star, while also taking into consideration a wide range of atmospheric pressures and potential albedo or greenhouse effects. However, seas and oceans don't just float around in space. The team used a basic 18th-century equation on the distribution of solar system planets, called the Titius-Bode law, to estimate the number of planets that could reside within these orbital ranges. These planetary figures were then multiplied by the abundances of each star type in the local Milky Way neighbourhood.

Their results showed ethane seas, not dissimilar to those found on Titan, should be as much as nine-times more common than water seas like Earth's. Nitrogen seas also seem far more frequent, especially around cooler red dwarf stars, whereas water worlds suffered from their liquid phase range overlapping considerably with the zone in which planets are tidally locked.

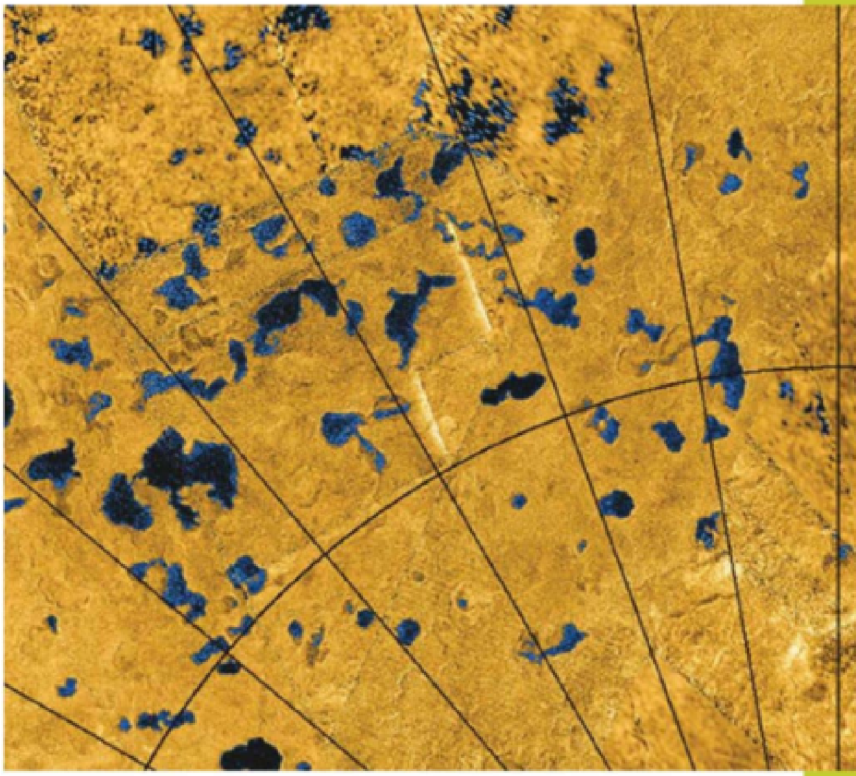
In such a scenario one face of the planet will permanently face the star and another faces away, creating huge differences in temperature. Without a mechanism to redistribute this heat water seas become difficult to envisage, with the hot side roasting in temperatures way above their boiling point and the permanent night side acting as cold trap of permanently frozen ice.

Ethane seas tend to sit outside this tidally locked region for red dwarfs. The liquid phase range is also very wide, increasing the chances of a planet, or multiple planets, forming inside. "If our calculations are even roughly right, you have many more seas of other substances [than water]," says Fernandez-Soto.

The group's negative view on tidal locking casts doubt on water oceans existing around many recent, headline-grabbing 'Goldilocks-zone' planets orbiting red dwarfs, such as TRAPPIST-1 and Proxima Centauri. Instead they suggest most water seas would orbit stars similar to our Sun, an unexpected result Fernandez-Soto takes comfort in. "When you find yourself in the most common situation, it is very satisfying. You are not weird. It doesn't call for fine-tuning."

Buoyed by this validation, the team write that their results suggest the traditional 'follow the water' strategy could be both overestimating the potential

Above: An infrared view of Saturn's moon Titan from NASA's Cassini spacecraft



Right: Radar images from NASA's Cassini spacecraft reveal many lakes on Titan's surface

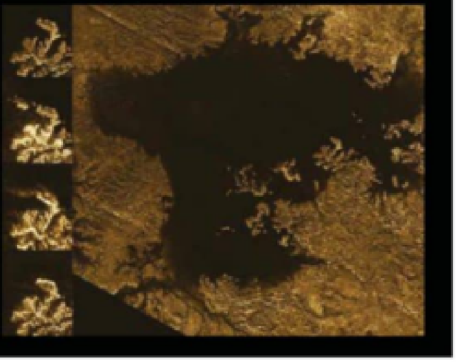
The fizzing experiment

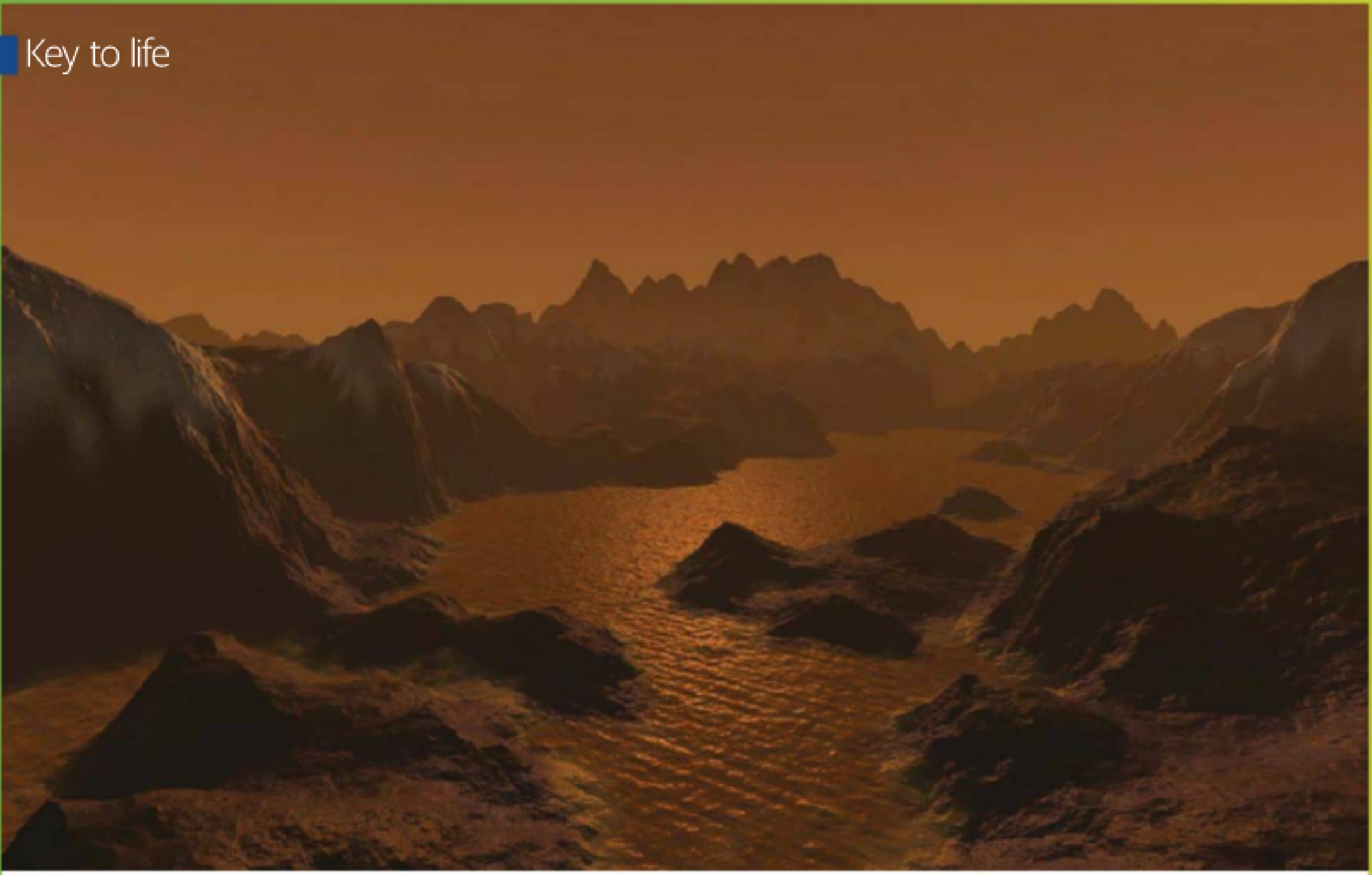
Solving the mystery of Titan's shapeshifting islands

Titan's magic islands are bright areas which have been shown to change shape, disappear and, in at least one case, reappear. They were first spotted in the hydrocarbon seas of Saturn's largest moon by the Cassini spacecraft.

Recent modelling by Michael Malaska of NASA's Jet Propulsion Laboratory (JPL) may have uncovered an explanation in the form of large amounts of nitrogen that can dissolve in the moon's lakes and seas.

Malaska showed this nitrogen can become unstable and start violently fizzing out of the solution, like an exploding fizzy drink. This is thought to occur when you get a mixing of liquid compositions on Titan, for example when run-off from a methane river following a rainstorm mixes into an ethane-rich lake.





for habitable water worlds around cooler stars and overlooking a vast population of other candidates with other types of seas. In fact, they go further. "If we were to find life elsewhere in the universe, its biological machinery would probably be based on ethane," they write.

However, there are significant caveats to state. Importantly, the study does not address the feasibility of waterless seas actually hosting the reactions for life. Also, the exclusion of the vast majority of tidally locked worlds ignores the potential for them to host moons that would continue to orbit, therefore able to redistribute heat through a standard day-night cycle.

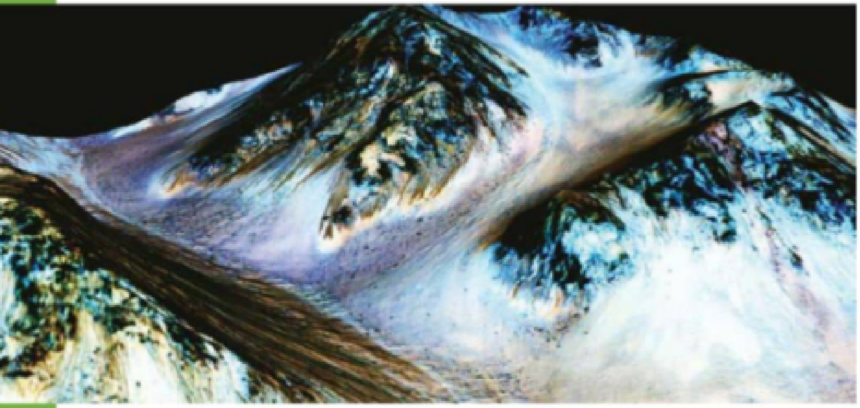
"We don't know anything about possible life in cold hydrocarbon environments," admits Fernandez-Soto, though in this uncertainty, and when factoring in the potential ubiquity of hydrocarbon seas in the galaxy, his team see hope. "We tend to avoid talking about seas different than water because we don't really know what is happening there. But we may have to take them into consideration because of how common they are," says Ballesteros.

Titan lakes expert Grima agrees that other liquid solvents might trigger life, and this demonstration of the prevalence of hydrocarbon seas might make a return trip to Saturn's moon a priority. "If this kind of world is that common in the galaxy, it makes it very compelling to bolster the exploration of Titan's seas and understand their potential to trigger life," he confirms.

Benner thinks it reasonable to assume that fluids with lower freezing points are abundant around other stars, though he doubts whether life can evolve within such seas after his own research on Titan's lakes concluded that dissolving any genetic polymer capable of heredity or evolution would be near impossible. "If they won't dissolve, there is no reason to have the fluid in the first place. Therefore future astrobiology missions should continue to look for signatures of surface H_2O," he explains.

William Bains' work back in 2004 proposed carbon-water life was not the only credible possibility, and more recent collaborations with Sara Seager at the Massachusetts Institute of Technology (MIT) continue to ask what other possibilities are out there. He describes the new calculations as an improvement on his own efforts over a decade ago, and the team's conclusions as "interesting". However, he is similarly doubtful of the ability of these cold liquids to dissolve the complex chemistry needed for life as we know it. He also questions the group's omission of the impact of photochemistry from star's UV rays, which he says renders methane lakes on Titan unstable over geological timescales, while water oceans on Earth remain unperturbed for billions of years. "So, [in regards to] the abundance of these liquids across the universe, I am sort of convinced, but does that mean that to 'follow the water' is a poor strategy for the search for life? I suspect not," he says.

Despite the scepticism from some of their predecessors, Ballesteros and Fernandez-Soto still believe their latest work has implications for strategies for finding extraterrestrial life. Even if the evolution of anything above basic molecules in these cold alien seas seems inconceivable, they believe it is impossible to ignore the abundance of worlds where puddles, lakes, seas or oceans of these hydrocarbons cover the surface. Maybe such prevalence can overcome the chemical odds stacked against them? Or perhaps even that is being too negative and Earth-centric in our view of what life can be, and the best places to create it?



Above: Impression of hydrocarbon pools on the surface of Titan

Left: These dark streaks, called recurring slope lineae, on Mars are inferred to have formed by ancient flowing water

© NASA/JPL Caltech; Steven Hobbs

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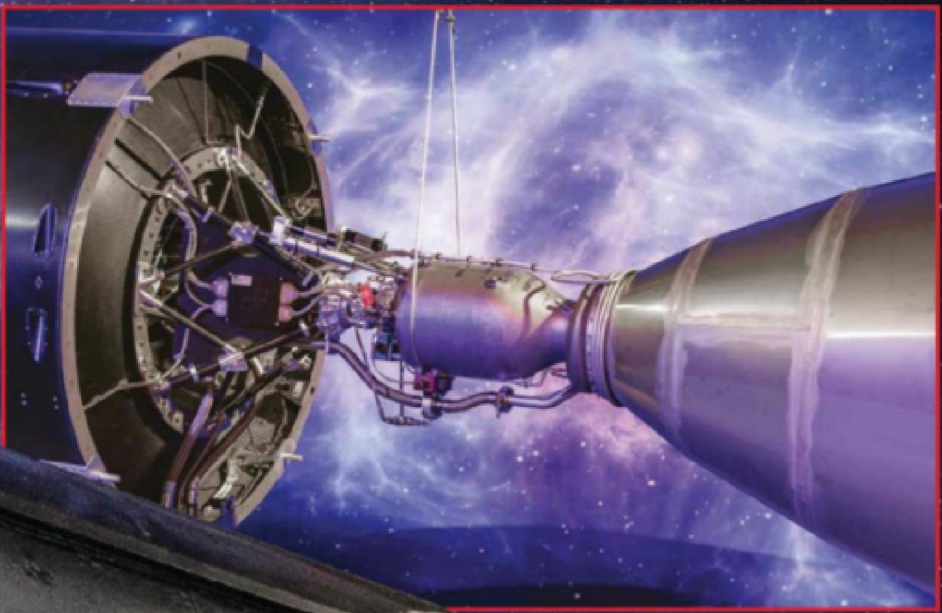
ORBEX'S PRIME ROCKET

Satellites will soon launch from Scotland, as revealed by a UK-based company with an exciting new prototype

Reported by Lee Cavendish

Right: The 3D-printed engine, if successful, will be an incredible feat for rocketry



Orbex, a UK-based spaceflight company, is making amazing headway in bringing satellite launches to the Scottish Highlands with the unveiling of its exciting two-stage rocket. At a private event on 7 February 2019, Orbex flaunted a prototype of the Stage 2 Prime rocket for the first time, announcing that it will be lighter, more efficient, better for the environment and will include the world's first 3D-printed rocket engine.

Orbex has only come into the public eye relatively recently; in July 2018 the UK Space Agency chose Orbex to launch from its spaceport in Sutherland, Scotland. From there it has gained amazing support from private and public crowds, making it Europe's best-funded private launch company. "Since the announcement in July 2018 that we had been chosen to launch from the Sutherland spaceport, Orbex has been on an incredible journey, largely behind the scenes," said Chris Larmour, Orbex CEO. "That is changing today as we publicly reveal the company's technical and commercial momentum. Not only do we have a full engineering prototype of the complete Stage 2 of the Prime rocket, but also a growing roster of customers hoping to be among the first to launch satellites from Scotland."

The Prime rocket has been completely rethought and redesigned by a team of aerospace engineers with experience in prestigious organisations such as NASA, ESA and Ariane. The new design uses a lightweight carbon fibre and aluminium composite that will make Prime launchers 30 per cent lighter and 20 per cent more efficient than any other small launcher, even outdoing some heavy launchers with regards to power per cubic litre.

The 3D-printed engine will be a revelation in rocketry, constructed from the same carbon fibre and aluminium composites, and will have advantages when it comes to the high temperatures and pressures endured during launch. When a rocket is launched, the heat and pressure can lead to stress on the joining and welding. The structure of this 3D-printed engine will withstand such temperatures and pressures. The rocket will also utilise bio-propane fuel, which is an environmentally friendlier renewable fuel source and will predictably cut carbon emissions by 90 per cent compared to fossil fuels.

Orbex's Prime rocket's maiden flight from the Sutherland spaceport will take place in 2021, carrying an experimental payload from another United Kingdom-based company – Surrey Satellite Technology Ltd. (SSTL). This event will mark a historic day for the UK and its commercial space industry by launching the homemade satellite aboard a homemade rocket from a home-based spaceport.

> "It will be lighter, more efficient, better for the environment and will include the world's first 3D-printed rocket engine"

© Orbex

© Kevin McGivern

CRIMES IN SPACE

There has never been a cosmic criminal, but as space travel widens will the current laws be able to cope?

Reported by David Crookes

What could possibly go wrong?

Astronauts refuse to work

Who or what:

Skylab 4: Gerald P. Carr, Edward G. Gibson, William R. Pogue

While not a crime, this three-man crew downed tools and turned off their radio communications with NASA ground control for a short period, feeling their workload was too heavy.

Satellite crashes into Canada

Who or what:

Kosmos 954

Reconnaissance satellite Kosmos 954 malfunctioned in 1978, re-entered the atmosphere and caused radioactive debris to spread over northern Canada. A claim was filed under the 1972 Space Liability Convention.

Astronaut confronts love rival

Who or what:

Lisa Nowak

As if to prove that astronauts don't always maintain a level head, Lisa Marie Nowak – who flew aboard STS-121 in 2006 – pleaded guilty to a charge of burglary and misdemeanour battery after confronting a love rival (on Earth) in 2007.

Apollo 7: the mutiny

The crew didn't want to follow certain orders from NASA

Walter M. Schirra

Walter M. Schirra was the commander of Apollo 7: the first of the Apollo missions to carry a human crew into space. About 15 hours into the flight he got a cold, felt bad and asked that a live TV broadcast be delayed to allow mission tests to be completed. "We do not have the equipment out; we have not had an opportunity to follow setting; we have not eaten at this point," he snapped at Mission Control, thereby disobeying the request for a camera to be turned on.

What was the penalty?

Unknown, but Schirra was already set to retire from NASA and had announced his intention.

Imagine if an astronaut went rogue one day, stealing another's belongings, smashing up the International Space Station (ISS) and murdering a colleague before fleeing the scene in a Soyuz capsule. It would, to put it mildly, be a pretty shocking series of events, and there is no doubt that the person would need to be punished. But who would bring that person to justice and where would they be tried? After all, there are no courts in space – at least not yet.

Great minds have pondered this question over the years, and it has been answered and revised thanks to the ongoing evolution of space travel. It has led to laws and codes being put in place to deal with potential trouble, as well as wide-ranging debates over how they could be extended in the future. For while currently only trained professional astronauts have zoomed into the night sky, it won't be long before civilians are riding alongside them.

"To my knowledge, private companies have not adopted any measures to deal with potential crime committed by future space tourists," says Dr Thomas Gangale, an expert in such matters who holds a doctorate of judicial sciences in space, cyber and telecommunications law from the University of Nebraska. But just what is in place to cover potential criminal acts in space today, and how many astronauts have actually fallen foul of them?

The answer to that last question is simple enough: astronauts have, at least to date, been very well behaved, so there have been no legal prosecutions brought against any of them for space-related matters. Yet that's not to say that this will always be the case. Fail to abide by rules laid down in the International Space Station International Governmental Agreement (IGA), and in particular within Article 22 which addresses criminal jurisdiction, and trouble won't be too far ahead.

"Space is a global commons and it is governed by international law," explains Professor Joanne Gabrynowicz, who has been teaching space law for 32 years. "So whatever criminal law is part of international law overall is potentially applicable to space."

Article 22 is important since it takes into account that the ISS is inhabited by people from various nations and thereby spells out how they should be dealt with in such an international environment should a crime be committed. "Canada, the European Partner States, Japan, Russia and the United States," it says, "may exercise criminal jurisdiction over personnel in or on any flight element who are their respective nationals." What this means is that those nations are ultimately responsible for their own citizens.

Donn F. Eisele

Schirra's irritability caught on: the other two crew members also felt uncooperative, and it didn't help that they also contracted a head cold. They had each devised a system for relieving their symptoms - they would pinch their noses and blow - but a problem loomed. Mission Control wanted them to wear their helmets for re-entry but Donn F. Eisele, along with Schirra and R. Walter Cunningham, refused, and they did so without. Mission Control was not at all happy at this second example of disobedience.

What was the penalty?

Unknown, but Eisele did serve as backup Command Module pilot for the Apollo 10 flight in 1969.

R. Walter Cunningham

R. Walter Cunningham, in his refusal to wear a helmet, also ran afoul of NASA management. He was worried that the re-entry would cause a problem with his ear drums. Mission Control had already told Schirra that he had "better be prepared to discuss in some detail when we land why we haven't got them on".

What was the penalty?

Unknown, but Cunningham headed up the Skylab Branch of the Astronaut Office before leaving NASA.

"In general, criminal conduct in outer space falls under the jurisdiction of the state which launched the person," says Gangale, and this covers anyone who commits assault, homicide or the wilful destruction of property while in space.

Indeed, should an astronaut do anything which affects the life or safety of a national of another partner state, or should it occur in, or cause damage to, the flight element of another partner state, then a law will be deemed to have been broken. In effect, if a British astronaut, for sake of an example, killed a French colleague in a module registered to the United States or wrecked the Russian section of the ISS, then he or she would be tried under British law.

"Astronauts are subject to their own national law and any applicable international law, including treaties and agreements entered into by the state of their nationality," Gabrynowicz adds. "To the extent that any of these include particular crimes, that portion of the law would be applicable."

Now there may be an unusual case where a government decides to let things lie unresolved, allowing the alleged perpetrator to effectively get off the hook. In those circumstances a fallback will kick in. "In the unlikely event that the partner state of the alleged perpetrator fails to consider the possibility of bringing charges then the 'victim' partner state may exercise jurisdiction over a non-national if some conditions are met," says Gabrynowicz. "If necessary the IGA can function as an extradition treaty."

But it doesn't stop there. In both cases the prosecuting country can expect everyone else to give support as and when it is needed. "The partners are legally obliged to provide mutual legal assistance, for example to recover evidence to be submitted to the competent court of a partner state," Gabrynowicz explains. In that sense there should be no barriers to justice, and no evidence should be withheld.

Yet how would this be dealt with on board the ISS itself? For that we turn to the space station's Code of Conduct, which applies to a crew member from the time he or she is assigned to an expedition until the completion of post-flight activities.

It establishes a clear relationship between ground and in-orbit management, a management hierarchy and a clear chain of command in-orbit - the ISS commander being ultimately responsible. It then

The Moon has to be free to explore for all states, and it falls under the agreement of the Outer Space Treaty

> "In general, criminal conduct in outer space falls under the jurisdiction of the state which launched the person"

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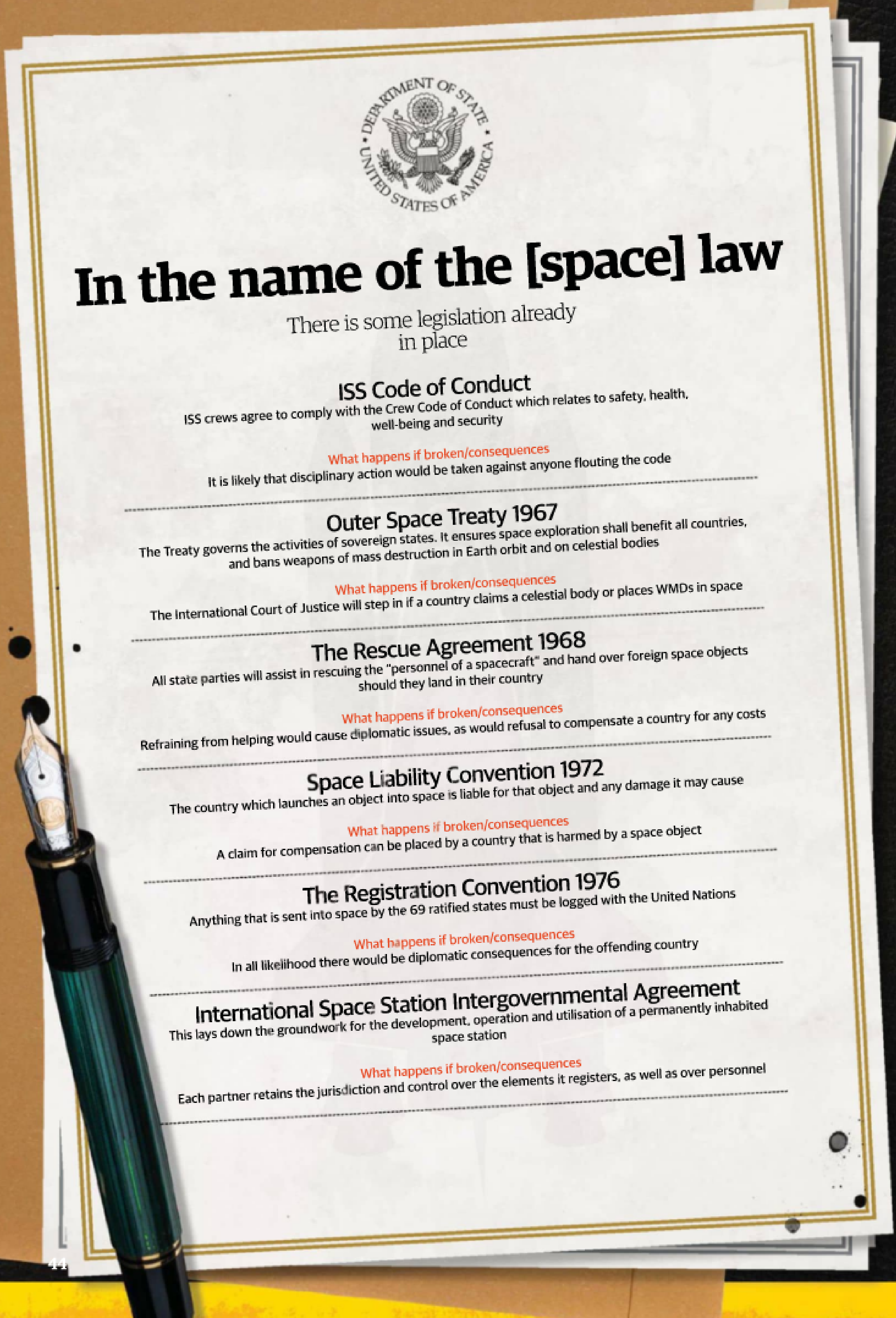


DEPARTMENT OF STATE
UNITED STATES OF AMERICA

In the name of the [space] law

There is some legislation already in place

ISS Code of Conduct

ISS crews agree to comply with the Crew Code of Conduct which relates to safety, health, well-being and security

What happens if broken/consequences

It is likely that disciplinary action would be taken against anyone flouting the code

Outer Space Treaty 1967

The Treaty governs the activities of sovereign states. It ensures space exploration shall benefit all countries, and bans weapons of mass destruction in Earth orbit and on celestial bodies

What happens if broken/consequences

The International Court of Justice will step in if a country claims a celestial body or places WMDs in space

The Rescue Agreement 1968

All state parties will assist in rescuing the "personnel of a spacecraft" and hand over foreign space objects should they land in their country

What happens if broken/consequences

Refraining from helping would cause diplomatic issues, as would refusal to compensate a country for any costs

Space Liability Convention 1972

The country which launches an object into space is liable for that object and any damage it may cause

What happens if broken/consequences

A claim for compensation can be placed by a country that is harmed by a space object

The Registration Convention 1976

Anything that is sent into space by the 69 ratified states must be logged with the United Nations

What happens if broken/consequences

In all likelihood there would be diplomatic consequences for the offending country

International Space Station Intergovernmental Agreement

This lays down the groundwork for the development, operation and utilisation of a permanently inhabited space station

What happens if broken/consequences

Each partner retains the jurisdiction and control over the elements it registers, as well as over personnel

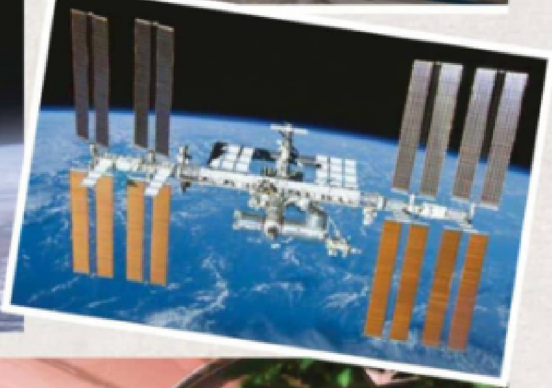
From top left (clockwise): Orion will carry a crew of four to the Moon, asteroids and Mars, but could long-term close proximity lead to space crimes?

One concern is how to keep astronauts happy - will they become less predictable the longer they are in space, and can future laws take that into account?

Most of the laws and rules in place relate to the International Space Station since that is currently the focus of human-based space exploration

It will be important to establish laws on Mars and decide who will be responsible for any humans who live and work there

Space tourism presents issues of its own since most who travel will not be vetted astronauts, unlike this Virgin Galactic chief astronaut instructor



sets standards for work and activities in space and on the ground and lays down the disciplinary regulations the astronauts must adhere to.

"ISS crew members' conduct shall be such as to maintain a harmonious and cohesive relationship among the ISS crew members and an appropriate level of mutual confidence and respect through an interactive, participative and relationship-oriented approach which duly takes into account the international and multicultural nature of the crew and mission," it says under the General Rules of Conduct.

But all that said, space travel is not going to be confined solely to the ISS. There are plans to zoom astronauts off to the Moon and to other planets such as Mars. Laws dealing with potential criminality must extend to these instances too, not only in terms of the destination, but how the astronauts travel.

For this, the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space – or the Outer Space Treaty, to give it a more manageable name – comes into play. Ratified by members of the United Nations, it is the legal framework for space agencies and it ensures that "each state which launches or procures the launching of an object into outer space, and each state from whose territory or facility an object is launched, is internationally liable for damage to a foreign state or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space."

Making clear that outer space includes the Moon and other celestial bodies, there is a stark takeaway from this, in particular to the laws governing travelling spacecraft. "The law will be determined by the nation that registers it in accordance with the Registration Convention," Gabrynowicz tells us. "If the spacecraft is from a nation that is not party to this treaty [which has not happened so far] then the law that applies would be public international law and the relevant law of that nation."

All of this means that many crimes are covered. "States have jurisdiction over universal crimes such as piracy, drug trafficking, hijacking, terrorism and human trafficking committed in outer space," Gangale tells us. Meanwhile, Gabrynowicz says: "The law on another planet would consist of already existing international law, the national laws that a nation passes to enable it to interpret and implement their obligations at international law and any treaties established for a specific planet."

But are they adequate? Here the answer is less clear cut, and that is mainly because of our collective approach to space so far. Up to now, everybody who has travelled has been carefully selected for their ability to deal with high-pressure situations. Astronauts don't generally flap when circumstances threaten to spiral out of control and their level-headedness means they are less prone to acting erratically. As such, the structure of the laws reflect this.

"The current criminal legal regime of outer space is far from robust, simply because there has been no perceived need [for it to be any different]," confirms Gangale. "State-sponsored astronauts undergo rigorous selection processes. But as space travel becomes affordable for private citizens, the need for greater specificity in criminal law will certainly develop in response."

To what degree such specificity will manifest itself is not yet known, and a lot will depend on

© NASA; Virgin Galactic

the nature of space tourism and how it will evolve. "The space tourist flights contemplated by Virgin Galactic and Blue Origin in the next few years will be suborbital and therefore of short duration, and I believe that for safety reasons passengers will be required to remain strapped to their seats throughout these flights, so there will be little opportunity for them to commit any criminal acts," Gangale says. "Such flights launched from US territory would be under the jurisdiction of US law, so any crimes committed would be subject to federal and/or state law."

Even so, experts agree that there will be a need to develop new laws. Indeed, Michelle Hanlon, associate director for the LL.M. program in air and space law at the University of Mississippi School of Law, tells us that it would have to cover the rights of tourists and those employed to take care of them.

"As I have noted in a recent paper, whether a tourist spending a few days on a space station hotel in lower-Earth orbit, a labourer overseeing the manufacture of products in space, a salvager harnessing and repurposing space debris or a scientist conducting research in cislunar, lunar or Martian orbit, private space stations will soon become commonplace," she says.

"These spacefarers - and the stations they will inhabit - fall within the gaps of the Outer Space Treaty regime. It would be worthwhile to develop universal laws in anticipation of these events - the commonality of humans living, working and vacationing in space - for a number of reasons."

She believes rules will need to be put in place to prevent unnecessary conflict which could give rise to a diplomatic crisis. She says we must also work to thwart the threat of dystopian tyranny on these private pockets of human civilisation. "We'll need to assure the safety of the hardy souls that venture into space as private citizens and work responsibly to develop international guidelines that will prevent disasters without stifling commercial industry, innovation and exploration," she continues.

There could also be a need to protect the planets and bodies we travel to. Currently there are no effective laws protecting the lunar environment, but Hanlon wishes for that to change. "Even under planetary protection protocols the Moon is considered a 'Category 1' in that there is no concern about contamination," she says. "Thus there is no possibility to commit a crime against the lunar environment." For that reason she is working with a number of organisations to determine whether and how we should consider protecting the Moon.

But what of bodies that are further flung? So far human space travel and exploration has been limited to the ISS and the Moon on relatively short trips, but if we expect a crew to fly to Mars, which will likely take six months minimum, then any stresses and strains could easily magnify. Perhaps in certain circumstances this could lead to someone acting out of character - and how that is dealt with, not just when that person gets back to Earth but while they are in the air, must be considered.

To that end we'd need to look at who would start criminal proceedings and rule on the outcome, and where - if a person needed to be separated - they could be detained. There is a danger that, depending on their skillset, punishment could have dire consequences for the mission. There would certainly be a problem should someone require long-term imprisonment, not least because of the burden that would place on a mission that could last for some time.

"The advent and proliferation of private space stations should be the mainframe from which we, as a society and global community, consider the regulation of extraterrestrial human civilisation," Hanlon says. It's clear there is a lot to think about as we ready ourselves to take human exploration and curiosity in space into directions which, some 50 years ago, were the preserve of science-fiction. A courtroom on Mars may one day be a reality.

> "We'll need to assure the safety of the hardy souls that venture into space as private citizens" **Michelle Hanlon**

Space laws cover travel to and from Earth and the International Space Station

© NASA

The 'storm' was caused by a powerful quasar

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A STORM IN A COSMIC TEACUP

NASA's Chandra Space Telescope captures a tempest in the universe

Reported by Samantha Mathewson

A quasar has caused a raging storm in a distant cosmic structure known as 'the Teacup'. The quasar, which is powered by a supermassive black hole, is located at the centre of a distant galaxy about 1.1 billion light years from Earth. The galaxy, formally known as SDSS 1430+1339, hosts a teacup-shaped structure, in which the quasar is brewing.

Quasars are among some of the brightest and most distant objects known in the universe. They are found only in galaxies with supermassive black holes, which gobble up matter near the galactic core and emit extreme amounts of radiation, according to a statement from NASA.

The signature 'handle' of the Teacup lies 30,000 light years from the black hole. This structure is believed to be a ring of galactic material surrounding a giant 'bubble', and was likely formed by one or more eruptions powered by the black hole.

Radiation from the black hole can cause high-speed galactic winds, also known as jets, to shoot out from either side of the quasar. These powerful jets likely blew a ring of galactic material into space, creating the 'bubble' found inside the handle of the Teacup, according to the statement.

Using NASA's Chandra X-ray Observatory, astronomers have been able to learn more about the evolution of the black hole and how its behaviour has changed over time. Previous studies suggested that the quasar was rapidly dying out. However, the new data from Chandra shows that the quasar is producing much more radiation than scientists previously thought, according to a 2018 study published in the *Astrophysical Journal Letters*.

The Chandra data also revealed that the quasar is heavily obscured by gas, which likely obstructed the view of optical telescopes used to study the structure in 2007. The clouds of gas could have prevented astronomers from detecting all the radiation emitted by the quasar, thus leading them to believe the structure was quickly fading away.

The X-ray data from Chandra was combined with images from The ESA and NASA's Hubble Space Telescope to create a stunning new view of the Teacup structure.

> "New data from Chandra shows that the quasar is producing much more radiation than scientists previously thought"

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INTERVIEW BIO

Dr Florence Raulin-Cerceau

Dr Florence Raulin-Cerceau is an associate professor at the National Museum of Natural History in Paris, France, and is also on the board of directors for Messaging Extraterrestrial Intelligence (METI) International. This organisation takes a more active approach than Search for Extraterrestrial Intelligence (SETI). Her research primarily consists of the history of SETI and astrobiology.

A workshop was recently held in Paris where scientists and philosophers discussed the Drake equation and the Fermi paradox, which can be summed up in one sentence: If aliens are abundant in the universe, why haven't we detected them yet?

Above: The Milky Way could be teeming with other habitable Earth-like planets

© NASA/JPL; United States Department of Energy; Tobias Roetsch

"WE'VE PROBABLY BEEN DETECTED BY EXTRATERRESTRIALS"

METI's (Messaging Extraterrestrial Intelligence) esteemed director, Dr Florence Raulin-Cerceau, reveals - if intelligent alien civilisations have located us, why we should be talking back - and how we need to communicate

Interviewed by Lee Cavendish

What is your role at METI International?
In my part, my research is focused on astrobiology and the pioneers of SETI, because there were pioneers at the end of the 19th century who had projects to send messages to the Moon, Mars and Venus, the closest celestial bodies to Earth. These projects were not put into practice - they were just theoretical - but it was interesting to see that even at this time, more than a century ago, some people thought it was possible to send a message to other planets, even with it being the planets in our Solar System and not exoplanets.

But the scientific reflection was interesting because it is funny to see that a century later, with our own thoughts, we are thinking about using the same medium of communication in the message. For instance, using mathematics to somehow dialogue with aliens - mathematics seems to be the easy way to begin a message. Not the whole content, but to begin the message with mathematical concepts, and we are doing the same thing now. It is interesting to see the conversions between the first ideas at the end of the 19th century and now.

What benefits do you think actively messaging alien life has over passive watching for signals?
This is one of Douglas Vakoch's [president of METI] aims at METI. He wants to send a message to other planets because he thinks that the inhabitation of Earth is already detectable. We already have radio signals, TV signals, many other signals that are spread out into outer space. He doesn't know exactly, but he suggests that it is already possible to be detected by aliens because a lot of our radio signals, and many other signals, that are going away from the Earth can be picked up by alien civilisations elsewhere in the cosmos.

His opinion is that if we are detectable, it is not really dangerous to send messages [into outer space], and perhaps we have to provide the first step in this organisation because it's important for future generations to know if we are alone or not in the universe. Our signals, whether artificial or natural, come from the human activity, and for him [Vakoch] it's important to try and have contact with what could turn out to be another civilisation in the galaxy. Even if he doesn't know where the civilisation is.

With the recent detection of exoplanets, we have new results that show that some could be inhabited. In the past, before 1995, we did not know that there were so many exoplanets. And some of them, or at least one of them, is inhabited.

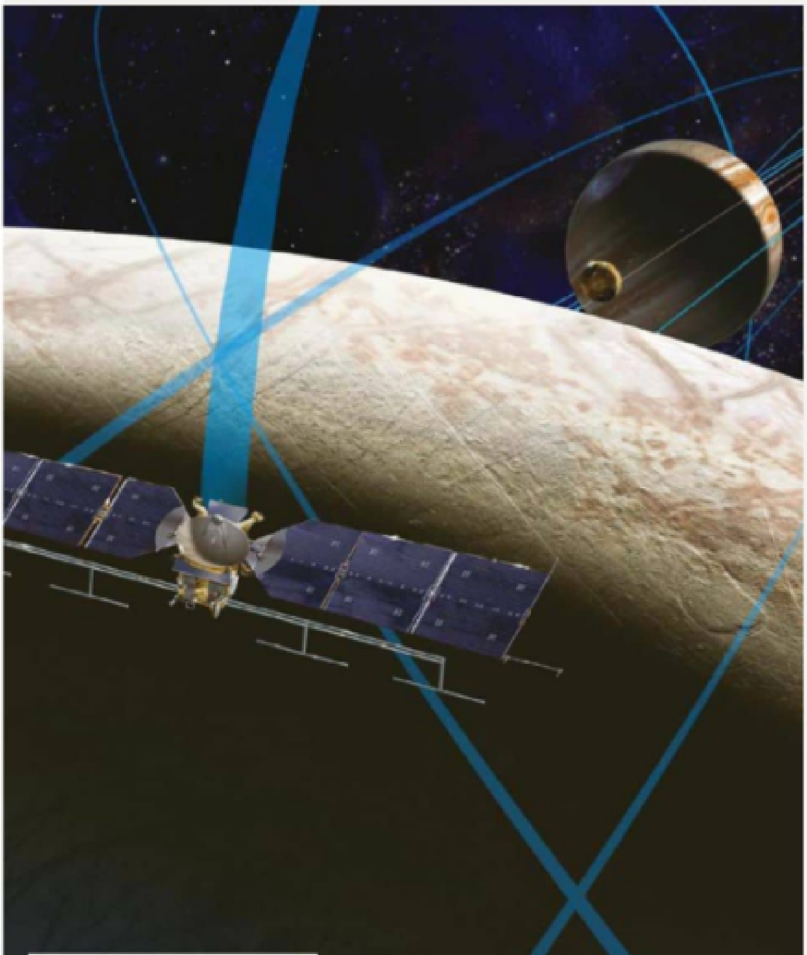
It is one for the philosophical thinkers, too, because it is important to think about the philosophical viewpoint, and not just the science viewpoint. In the meantime, METI are working on the contents of this message, which languages would be possible to be sent and so on.

Do you think it is a better idea to send messages in physical form, for example Voyager's Golden Records, or as a radio signal, for example the Arecibo message?
I think radio signals are better because it's possible

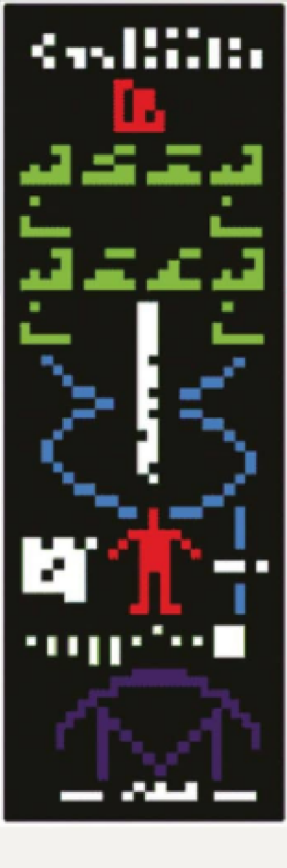
"We already have radio signals, TV signals, many other signals that are spread out into outer space"

Left: The Fermi paradox points out the contradiction between a high probability of alien life and low evidence

Below: Voyager's Golden Record includes a recorded message, as well as visual diagrams to help understand it



Left: NASA's Europa Clipper mission will launch to Jupiter's moon in 2023



Bottom left: The Arecibo message sent via radio signals describes the human race in binary code

Below: The search for ancient life on Mars has had its best results with the arrival of Mars exploration rovers

to send them to target planetary systems. And also, we can send a lot of information with a very simple technology. With our present technology, we are not able to do the same thing with physical messages.

What is your stance on whether or not there is alien intelligence? Do you believe that it's definitely out there?

Yes, I believe it is possible, because as you know we have found many exoplanets. A lot of exoplanets have been discovered, and some of them could be like our Earth. Maybe life could be possible on some of these planets. So why would Earth be the only planet with inhabitance, even if it's very simple life? I think it's possible to have simple life on other planets - and why not on the ones we don't know about.

We are looking, but we don't know. But my opinion is that it's possible, because of the many discoveries of exoplanets. But life, of course, is not so easy to create. The birth of life on a planet is not so easy, so we don't know if it's an event that is very frequent or not.

Would it be possible for life to arise from a different chemistry to our own? For example, non-carbon-based lifeforms.

The usual thought surrounding that is that carbon is necessary to have some combination of atoms that are very efficient to build life. So life built on other atoms, for example silicon, is not the usual hypothesis in the scientific community. So carbon seems to be necessary to build life on other planets too, like on Earth.

Why do you think we have not seen life elsewhere in the universe yet?

Because it is difficult. In the Solar System there have been space exploration missions to find out if there is life on other planets. Until now, we haven't found any life. We are looking for past microbial life on Mars, because Mars maybe had temperatures that were very good for life at the beginning of the life of this planet.

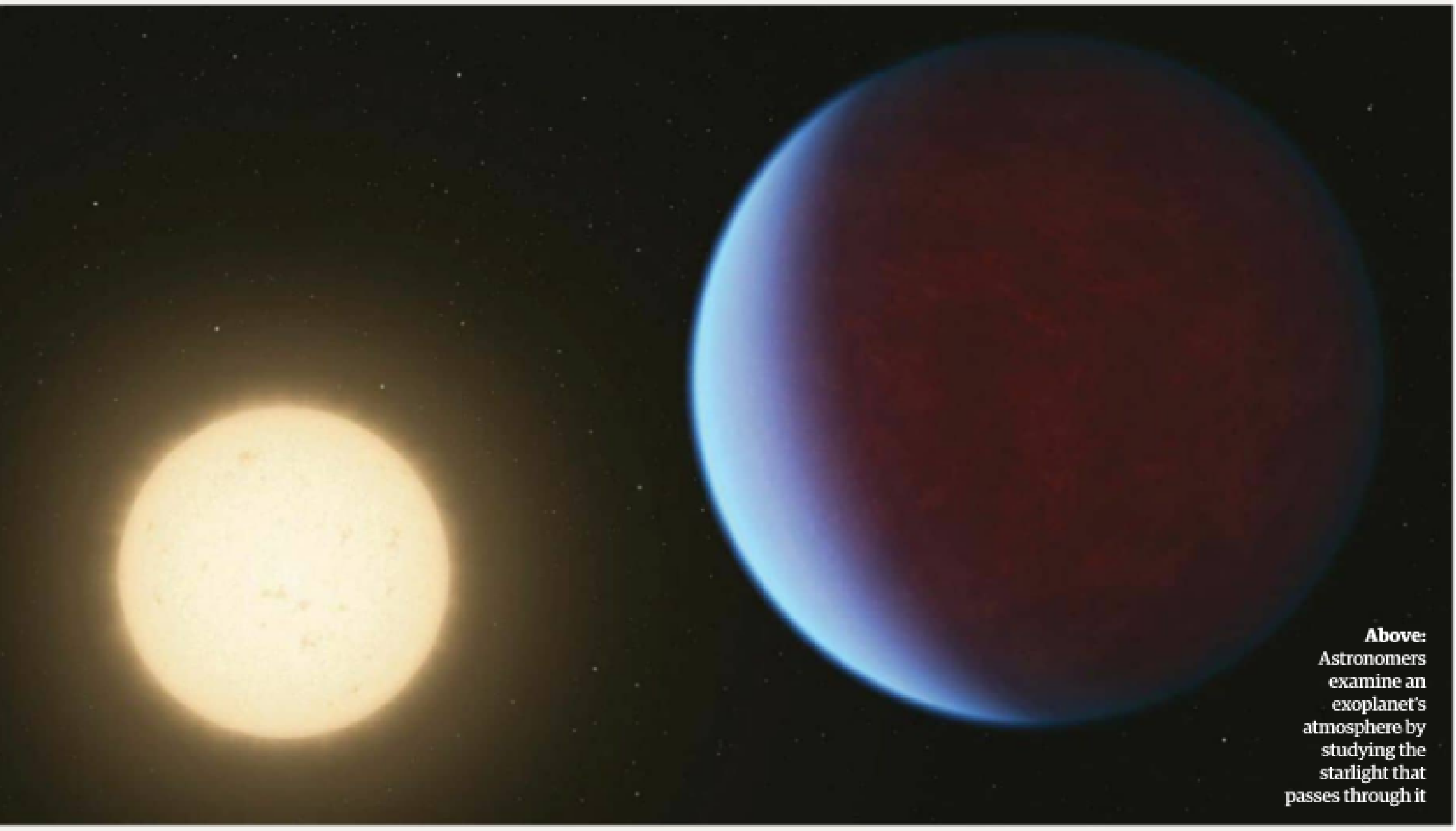
But we don't know. In fact, now there is no life on Mars, but maybe microbes could have emerged at the very beginning of the planet and now they are extinct. So astronomers are basically looking for microfossils. Microfossils are the next step in the exploration of Mars.

What about other planets in the Solar System?

[There could be evidence on] other planets in the Solar System, maybe on the satellites around giant planets such as Jupiter or Saturn. There is the possibility of life in the oceans inside these big, big moons, like Europa, because they have liquid water in their interior. However, these hypotheses are really just speculation because we have no concrete evidence of life in another place in the Soar System, except Earth. And far away? No.

On exoplanets it is even more difficult to detect life. We are too far away, so we have to detect non-direct evidence. We have to detect products of life such as biosignatures - compounds in the atmosphere. This is evidence for the product of exolife. We have to undergo spectroscopic analysis

© NASA/JPL-Caltech; Frank Drake (UCSC) et al./Arecibo Observatory (Cornell/NAIC)



Above: Astronomers examine an exoplanet's atmosphere by studying the starlight that passes through it

and other non-direct methods to detect life in other planetary systems.

In the Solar System, we can send probes to see if there is life. It is difficult, but it is simpler than exploring exoplanets, as they are too far away. We have to wait for biosignature detections around the planets and to detect special compounds, for example carbon compounds, which could be products of other life. It will soon be possible to detect this signature in exoplanet atmospheres with future telescopes. It is the next step for bioastronomy, people working on exoplanets and people looking for life elsewhere.

What are the implications of knowing that life can arise on the moons of planets for the search for alien life?

There are [planned] space missions which are expecting to look for life on moons of the giant planets in our Solar System. But for other planetary systems it is even harder to see if there is life around exoplanets, so it's even more difficult to look at the atmospheres of their moons, as they are so much smaller. I think we have to wait a few years to have results in that direction because now we are just at the beginning of detecting compounds in the atmospheres of exoplanets, so you can imagine for the moons of exoplanets it is a lot harder. Maybe in the future we will know about exomoons.

Would it be possible to transport life from one planet to another? Do you think that is how life on Earth came about?

This hypothesis, referred to as 'panspermia', was first suggested by Anaxagoras during the antiquity era. At the end of the 19th century it was revived by Hermann Richter, a German botanist, who developed the idea in scientific terms. Since this time, it's a very controversial idea. Germs [microorganisms] travelling without any protection in space are quickly killed by strong ultraviolet radiation.

Experiments have been done to test this hypothesis, and the conclusion is the following one: germs could [potentially] survive interplanetary travels if they are in a sheltered environment, deeply embedded in a meteorite, for instance. The probability to survive to then enter into another atmosphere could also be a problem.

In my opinion - but it's just my opinion - I don't think it's the way life has appeared on Earth.

How do you see the future of METI and the search for extraterrestrial life going?

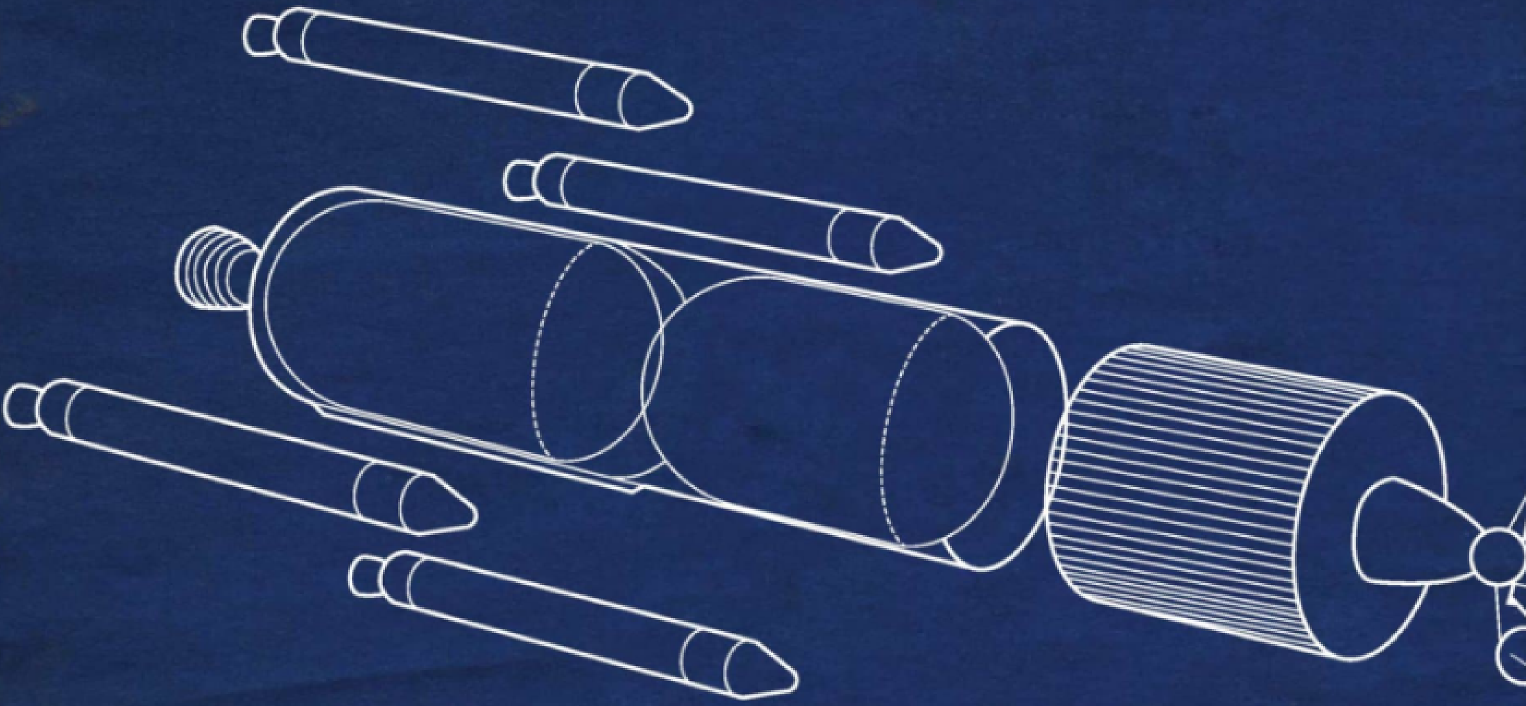
I think METI is very important because it is the first international organisation which is dealing with such topics. SETI is largely debated around the world and in many countries, especially in the United States with the SETI institute, but also in Europe, in the UK and in France. But METI is the first time where there is active collaboration, and I hope this organisation will be able to continue and to send a message [in the future]. This isn't the only aim of the organisation. As we showed in a recent METI workshop in Paris, France, it is to gather scientists, philosophers and sociologists to debate about topics, such as the topic of the Fermi paradox or topics related to the Drake equation.

What is the Drake equation?

The Drake equation is an important equation written by Frank Drake in the 1960s detailing the seven parameters which can be studied, and we can see our science evolve with this Drake equation. We can reflect on each part of the equation, such as the lifetime of a civilisation, if there are many planets that are habitable and other parameters like that.

It is very interesting, and the METI organisation is aiming to build a network of people to have workshops, meetings and scientific reflections around all these parameters of the equation and the Fermi paradox. So it's not just about sending a message, it's to have a broader reflection about life in the universe.

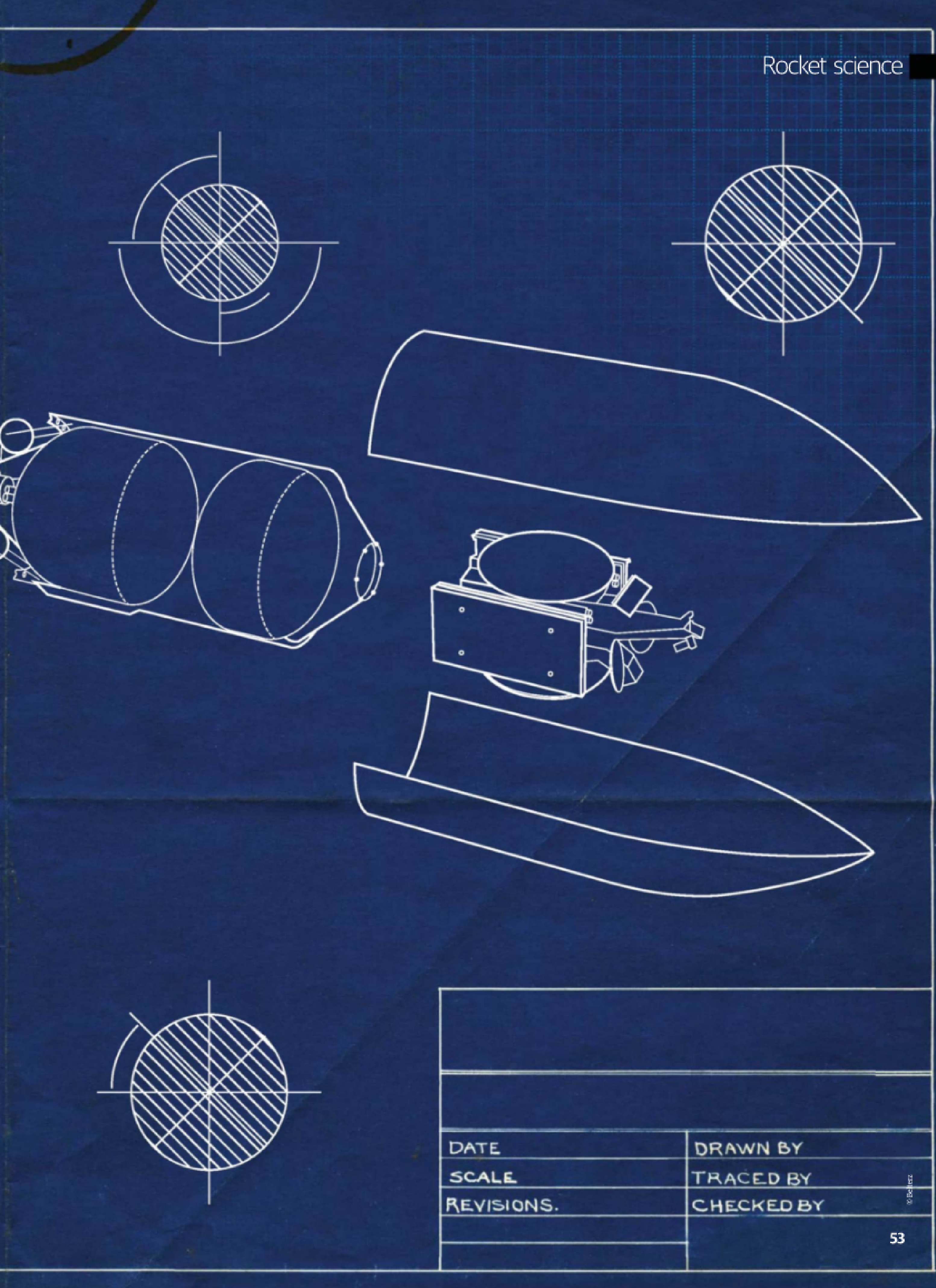
> "We have to undergo spectroscopic analysis and other non-direct methods to detect life in other planetary systems"



Bluffer's guide to ROCKET SCIENCE

Rockets of all kinds are still our only way of reaching space – but just how do they work?

Written by Giles Sparrow



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1 How rockets lift off

Rockets burn through most of their fuel in the first few minutes of their flight as they battle against Earth's gravity

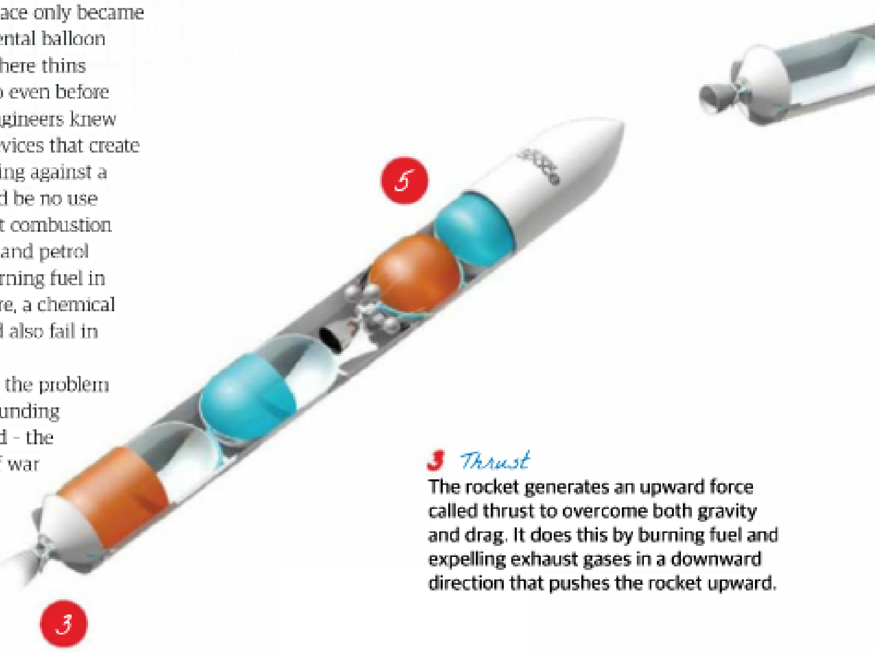
Writers and inventors have dreamt of exploring the universe beyond Earth for centuries, but the real challenges of travelling into space only became clear in the 19th century. Experimental balloon flights showed that Earth's atmosphere thins out rapidly at high altitudes, and so even before powered flight became a reality, engineers knew that wings, propellers and other devices that create a forward or upward force by pushing against a surrounding medium like air would be no use in space. Another problem was that combustion engines – machines such as steam and petrol engines that generate power by burning fuel in the oxygen from Earth's atmosphere, a chemical reaction called combustion – would also fail in airless space.

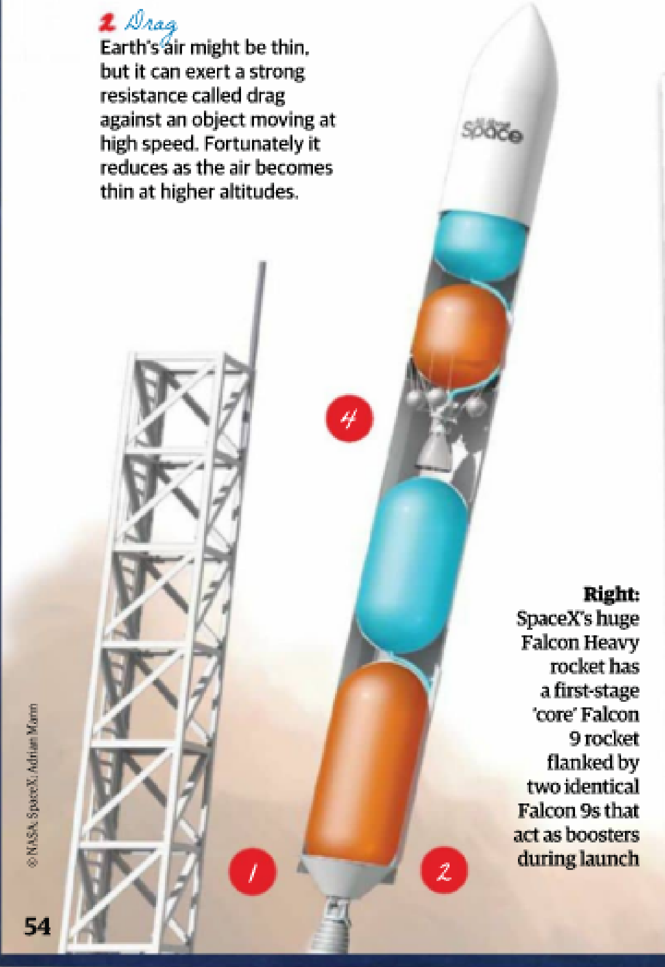
Fortunately, a device that solved the problem of generating force without a surrounding medium had already been invented – the rocket. Initially used as weapons of war

1 Gravity
The force of gravity pulls everything towards the centre of the Earth, exerting a downward force of 9.8 newtons per kilogram on every part of the rocket.

2 Drag
Earth's air might be thin, but it can exert a strong resistance called drag against an object moving at high speed. Fortunately it reduces as the air becomes thin at higher altitudes.

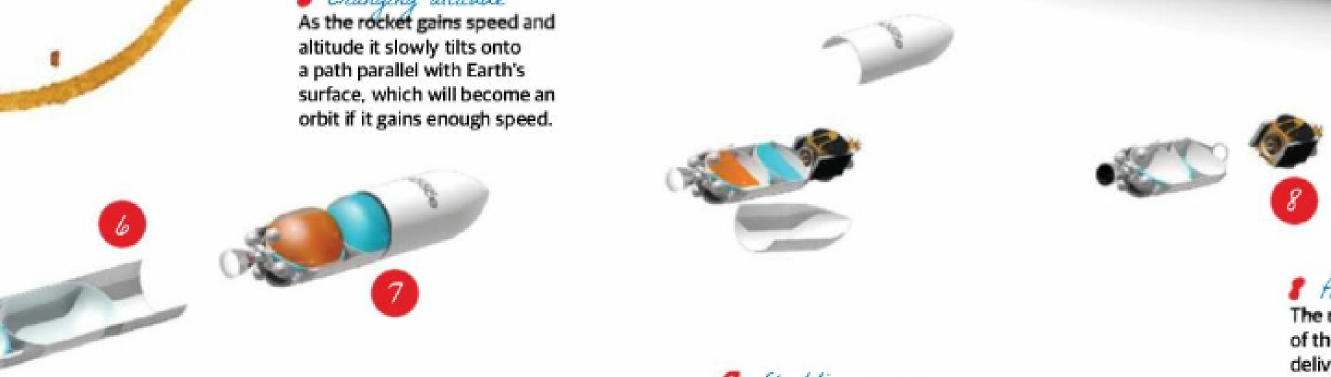
3 Thrust
The rocket generates an upward force called thrust to overcome both gravity and drag. It does this by burning fuel and expelling exhaust gases in a downward direction that pushes the rocket upward.





Right: SpaceX's huge Falcon Heavy rocket has a first-stage 'core' Falcon 9 rocket flanked by two identical Falcon 9s that act as boosters during launch

© NASA, SpaceX; Adrian Mann



4 Slow start
At launch a rocket's weight is at its greatest. Even with the rockets producing maximum thrust they produce barely enough power to lift the rocket off the ground.

5 Rocket stages
Most rockets are designed with two or more stacked units called stages. The lowermost stage fires its engines until they are exhausted, then separates and falls away to reduce the overall mass being carried further towards space.

6 Changing altitude
As the rocket gains speed and altitude it slowly tilts onto a path parallel with Earth's surface, which will become an orbit if it gains enough speed.

7 Shedding mass
As the rocket continues to burn fuel its weight reduces, so although the thrust force from its engines remains constant, it has a greater accelerating effect.

8 Payload
The uppermost stage of the launch vehicle, delivered into orbit, is known as the payload. This may consist of a satellite or spacecraft, often with a separate rocket stage for further manoeuvres.

Left: The Space Shuttle's unique design channelled propellant from an external tank to the Shuttle's main engines during launch, while two large solid rocket boosters assisted

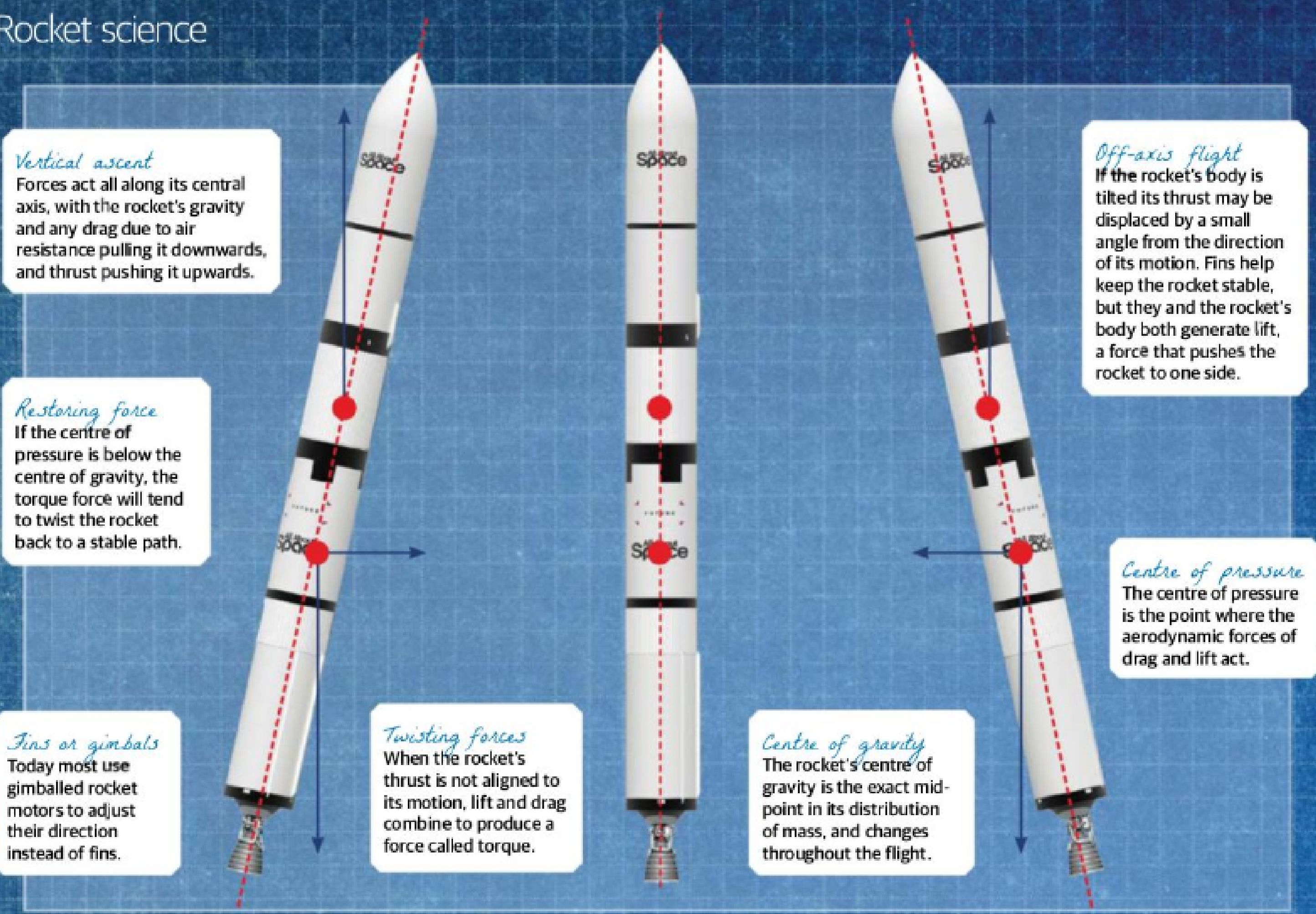
> "Rockets generate a force in one direction, called thrust, by the principle of action and reaction"

or in fireworks, rockets generate a force in one direction, called thrust, by the principle of action and reaction – exhaust fumes released by explosive chemicals are pushed out of the back of the rocket at high speed, and as a result the rocket is pushed in the other direction, regardless of any surrounding medium. The key to using rockets in space is simply to carry another chemical called an 'oxidant' that can perform the same role as oxygen in the Earth's air and allows the fuel to combust.

The first person to seriously study the rocket's potential for space travel, a Russian schoolteacher and amateur scientist called Konstantin Tsiolkovsky, first published his conclusions in 1903. He correctly identified the moment of launch as one of the biggest challenges – the moment where the rocket has to carry all the fuel and oxidant it needs to reach space – as its weight is at a maximum and a huge amount of thrust is needed simply to get it moving at all. As the rocket gets underway it sheds mass through its exhaust, so its weight is reduced and the same amount of thrust will have a greater effect in terms of accelerating the rest of the rocket. Tsiolkovsky came up with various rocket designs and concluded that the most efficient set-up was a vertically launched vehicle with several 'stages' – each a self-contained rocket that could carry the stages above it for a certain distance before exhausting its fuel, detaching and falling away. This principle, still widely used today, reduces the amount of 'dead weight' that needs to be carried all the way into space.

Tsiolkovsky devised a complex equation that revealed the necessary thrust force needed for any given rocket manoeuvre, and the 'specific impulse' – how much thrust is generated per unit of fuel – needed for a rocket to reach space. He realised that the explosive rocket propellants of his time were far too inefficient to power a space rocket, and argued that liquid fuels and oxidants, such as liquid hydrogen and liquid oxygen, would ultimately be needed to reach orbit and beyond. Although he did not live to see his work recognised, Tsiolkovsky's principles still underpin all of modern rocketry.

The Delta II rocket's first-stage core was assisted by nine separate solid-rocket boosters during launch



Vertical ascent
Forces act all along its central axis, with the rocket's gravity and any drag due to air resistance pulling it downwards, and thrust pushing it upwards.

Restoring force
If the centre of pressure is below the centre of gravity, the torque force will tend to twist the rocket back to a stable path.

Fins or gimbals
Today most use gimballed rocket motors to adjust their direction instead of fins.

Twisting forces
When the rocket's thrust is not aligned to its motion, lift and drag combine to produce a force called torque.

Centre of gravity
The rocket's centre of gravity is the exact mid-point in its distribution of mass, and changes throughout the flight.

Off-axis flight
If the rocket's body is tilted its thrust may be displaced by a small angle from the direction of its motion. Fins help keep the rocket stable, but they and the rocket's body both generate lift, a force that pushes the rocket to one side.

Centre of pressure
The centre of pressure is the point where the aerodynamic forces of drag and lift act.

2

Taking flight

Rockets must delicately balance and control powerful forces in order to make it through Earth's atmosphere into space

A rocket generates thrust using a controlled explosion as fuel and oxidant undergo a violent chemical reaction. Expanding gases from the explosion are pushed out of the back of the rocket through a nozzle – a specially shaped exhaust that channels the hot, high-pressure gas created by combustion into a stream that escapes from the back of the nozzle at hypersonic speeds, more than five-times the speed of sound.

Isaac Newton's third law of motion states that every action has an equal and opposite reaction, so the 'action' force that drives the exhaust out of the rocket nozzle must be balanced by an equal and opposite force pushing the rocket forwards. Specifically this force acts on the upper wall of the 'combustion chamber', but since the rocket motor is integral to each rocket stage, we can think of it acting on the rocket as a whole.

Although the forces acting in both directions are equal, their visible effects are different because of another of Newton's laws which explains how objects with greater mass need more force to accelerate them by a given amount. So while the 'action' force rapidly accelerates a small mass of exhaust gas to hypersonic speeds each second, the equal 'reaction' force produces a far smaller acceleration in the opposite direction on the far greater mass of the rocket.

As the rocket gains speed, keeping the direction of motion closely aligned with the direction of thrust is critical – gradual adjustments are needed to steer the rocket towards an orbital trajectory, but a severe misalignment can send the rocket whirling out of control. Most rockets, including the Falcon and Titan series and the Saturn V Moon rocket, steer using 'gimballed' engines, mounted so that the entire rocket motor can pivot and vary the direction of its thrust from moment to moment. Other steering options include using external vanes to deflect the exhaust gases as they escape the rocket engine – most effective with solid-fuelled rockets that lack a complex motor – and auxiliary engines – small 'thruster' rockets mounted on the sides of the rocket stage.

> "Keeping the direction of motion closely aligned with the direction of thrust is critical"

© NASA, Adrian Mann, Bellerz

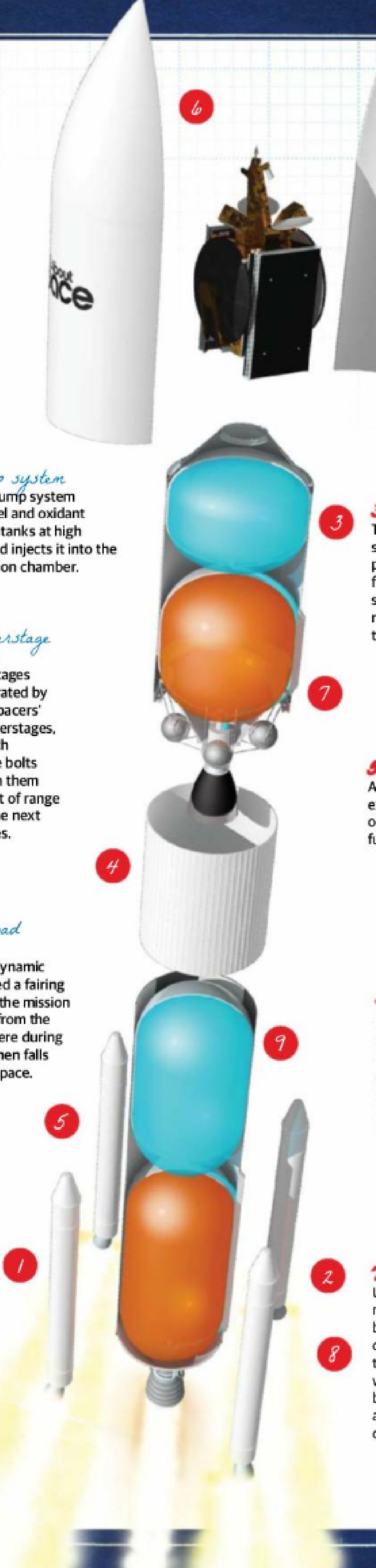
3 How a rocket's motors work

Rocket engines are complex machines that must endure ferocious heat and pressure

Modern rocket motors have come a long way from fireworks. Relatively simple solid rockets, most often used as boosters to provide extra thrust at launch, still rely on the same basic principle of igniting a tube containing a combustible mix of fuel and oxidant. Once ignited, a solid rocket will continue to burn until its fuel is exhausted, but the rate at which fuel is burnt - and therefore the amount of thrust - can be controlled by changing the amount of surface exposed to ignition during different times in the rocket's flight. This can be done by packing the fuel/oxidant mix with a hollow gap down the centre, running along the length of the rocket. Depending on the profile of this gap, which may be circular or star-shaped, for instance, the amount of exposed surface will change during the flight.

The more widespread liquid-fuelled rockets are far more complex. Typically they involve a pair of propellant tanks - one each for the fuel and the oxidant - connected to a combustion chamber through a complex maze of pipes. High-speed turbopumps driven by their own independent motor systems are used to deliver liquid propellant into the chamber through an injection system. The rate of supply can be throttled up or down depending on requirement, and fuel can be injected as a simple jet or a fine spray. Inside the combustion chamber an ignition mechanism is used to begin combustion - this may be a jet of high-temperature gas, an electric spark or a pyrotechnic explosion. Rapid ignition is critical - if too much fuel/oxidant mixture is allowed to build up in the combustion chamber than a delayed ignition can generate enough pressure to blow the rocket apart, a catastrophic event that rocket engineers laconically refer to as a 'hard start' or 'rapid unscheduled disassembly' (RUD).

The detailed design of a liquid rocket stage can vary a lot depending on its fuel and other requirements. Some of the most efficient propellants are liquefied gases such as liquid hydrogen, which is only stable at very low temperatures - around -253 degrees Celsius (-423 degrees Fahrenheit). Once loaded aboard the rocket these 'cryogenic' propellants must be stored in heavily insulated tanks. Some rockets avoid the need for an ignition mechanism using 'hypergolic' propellants that ignite spontaneously on contact with each other.



1 Boosters
Solid rockets make ideal boosters for use during liftoff. Strapped around a central liquid-fuelled 'first stage', they fall away when exhausted.

2 Pump system
A turbopump system draws fuel and oxidant from the tanks at high speed and injects it into the combustion chamber.

3 Propellant tanks
The interior of each stage is filled with large propellant tanks for fuel and oxidant - fuels such as liquid hydrogen may be efficient, but they are also bulky.

4 Interstage adaptor
Rocket stages are separated by empty 'spacers' called interstages, fitted with explosive bolts that push them safely out of range before the next stage fires.

5 Ignition system
An electric spark, explosive charge or jet of hot gas ignites the fuel/oxidant mix.

6 Payload fairing
An aerodynamic case called a fairing protects the mission payload from the atmosphere during launch, then falls away in space.

7 Upper stage
Upper-stage rockets are smaller but often more complex than the lower stages, with the ability to be switched off and re-ignited at different times.

8 Combustion chamber
Fuel and oxidant undergo violent combustion, creating expanding gases that are forced out through a shaped nozzle at the bottom. This generates upward thrust in the rocket motor itself.

9 Solid rockets
Solid rockets have a simpler design, with a mix of fuel and oxidant that ignites when triggered and burns continuously until exhausted.

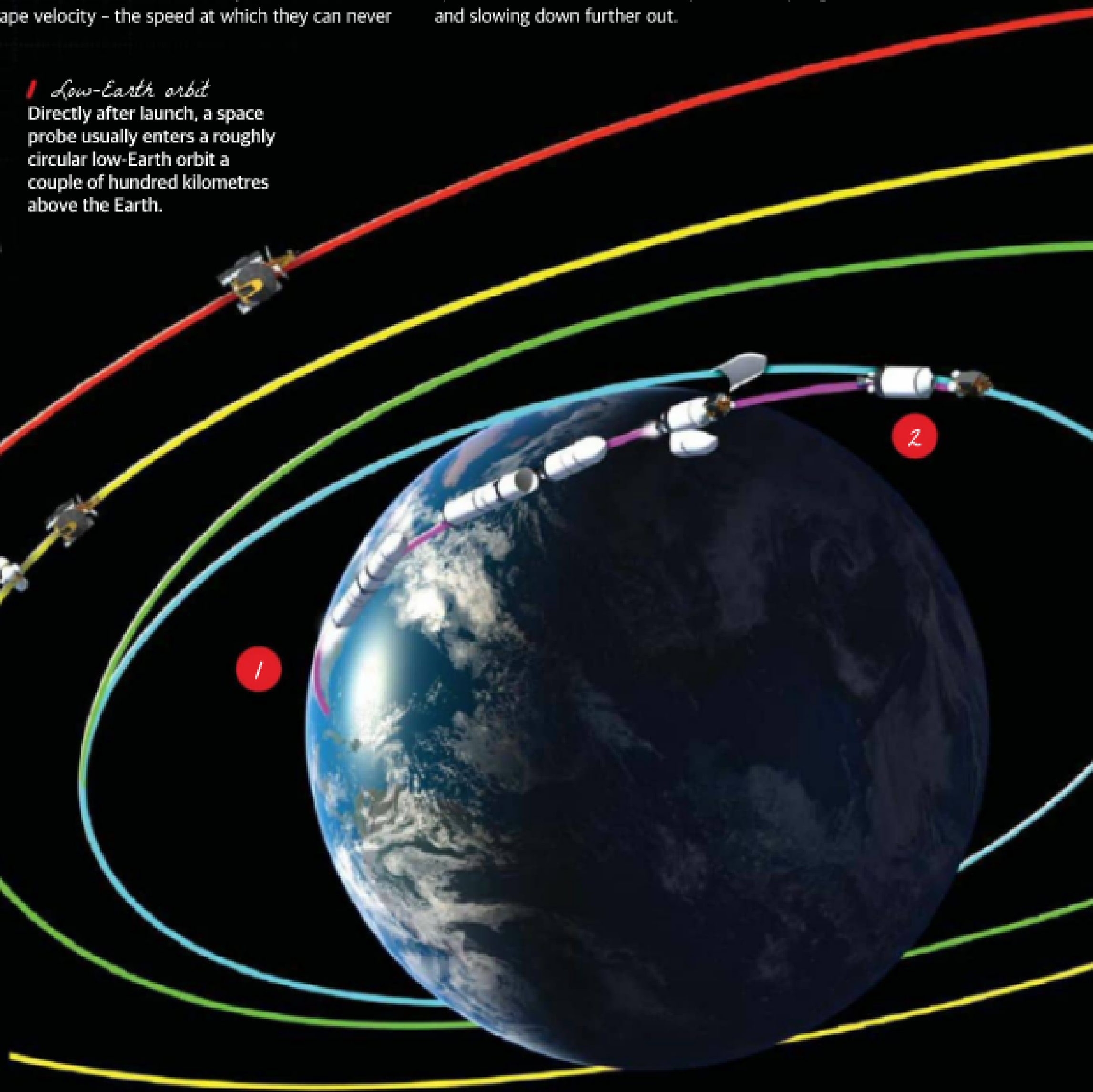
4 Interplanetary travel

Rockets are the key to exploring our Solar System – but how do they go from orbit to deep space?

Below: Nuclear thermal rockets are a hypothetical way of generating large amounts of thrust for sustained periods - they could one day shorten the journey time to other planets

The first stage of any spaceflight involves launch from Earth's surface into a relatively low orbit around 200 kilometres (124 miles) up, above the vast majority of the atmosphere. Here gravity is almost as strong as it is on the surface, but friction from Earth's upper atmosphere is very low, so if the uppermost stage of the rocket is moving fast enough it can maintain a stable circular or elliptical trajectory where the pull of gravity and the vehicle's natural tendency to fly off in a straight line cancel each other out.

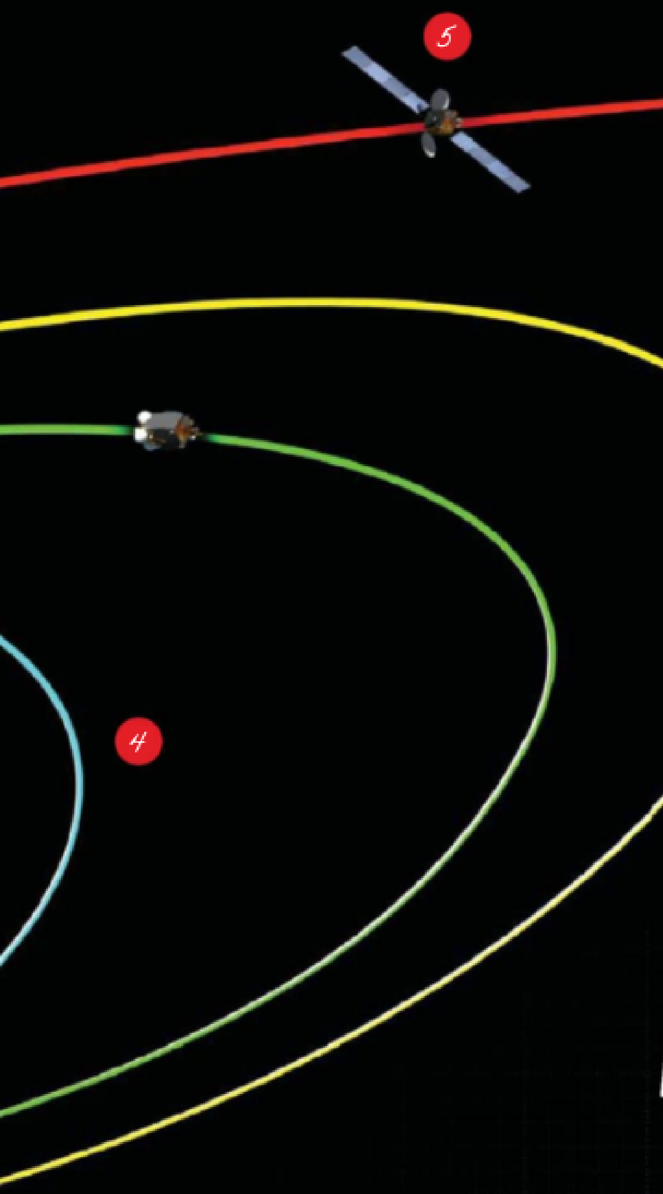
Many spacecraft and satellites travel no further than this low-Earth orbit (LEO), but those destined to leave Earth entirely and explore the wider Solar System need a further boost in speed to reach escape velocity – the speed at which they can never be pulled back by our planet's gravity. The escape velocity at Earth's surface – 11.2 kilometres (6.9 miles) per second – is about 50 per cent faster than the typical speeds of objects in LEO. It gets lower at a greater distance from Earth, and probes bound for interplanetary space are often first injected into elongated or elliptical orbits by a carefully timed burst of thrust from an upper-stage rocket, which may remain attached to the spacecraft for the rest of its interplanetary flight. In such an orbit the spacecrafts' distance from Earth can range from hundreds to thousands of kilometres, and its velocity will also vary, reaching a maximum when the spacecraft is closest to Earth, a point called perigee, and slowing down further out.



1 *Low-Earth orbit*
Directly after launch, a space probe usually enters a roughly circular low-Earth orbit a couple of hundred kilometres above the Earth.

2 *Ellipse around the Earth*
One or more precisely timed rocket burns nudge the spacecraft onto a more elliptical trajectory that varies in distance from Earth.

© NASA, SpaceX, Adrian Mann



4 Close burn
The Oberth effect allows a spacecraft's rockets to deliver more thrust for a set amount of fuel when it is already moving at high speed and close to Earth.

5 Hohmann transfer orbit
A final burn allows the probe to break free from Earth on a trajectory that looks spiral from our point of view, but is actually a segment of an elliptical orbit around the Sun.

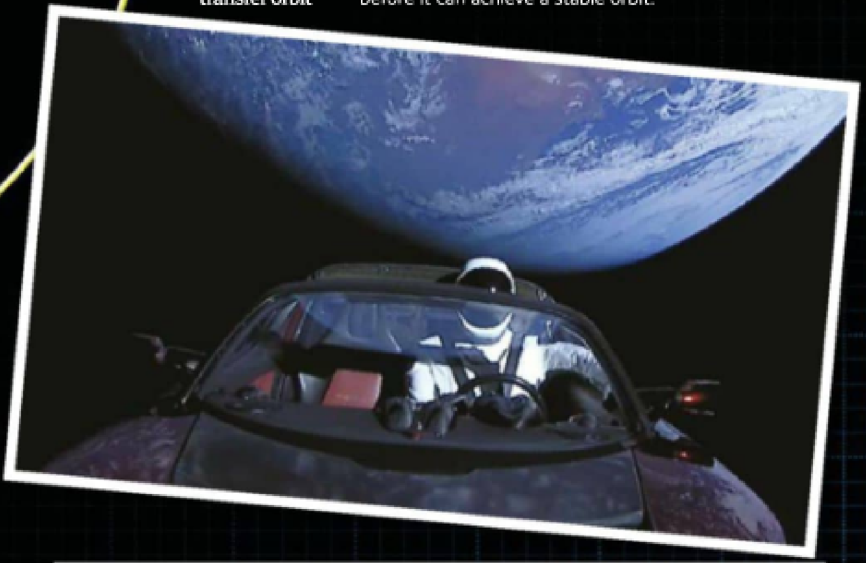
3 Picking up speed
In an elliptical transfer orbit the probe moves more slowly at greater distance from Earth, and much more quickly around its closest approach.

Surprisingly, however, the critical rocket burn used to escape into interplanetary space is usually made when the spacecraft is near perigee. This is due to the so-called 'Oberth effect', an unexpected property of rocket equations that means a rocket is more efficient when it is moving at higher velocity. One way to understand this is that burning a spacecraft's fuel allows the engine to utilise not only its chemical energy, but also its kinetic energy, which is greater at higher speeds. On balance, the additional rocket thrust needed to reach escape velocity from a low altitude at higher speed is less than that needed to escape from a high altitude when moving at a lower speed.

Spaceflight engineers and mission planners often refer to the 'Delta-v' required to accomplish a specific flight manoeuvre, such as a change in orbit. Strictly speaking the term 'Delta-v' means change in velocity, but engineers use it specifically as a measure of the amount of 'impulse', or thrust force over time, needed to accomplish a manoeuvre. Broadly speaking, missions are planned around a 'Delta-v budget' – how much thrust they can generate for how long using the spacecraft's onboard fuel supplies.

Sending a spacecraft from one planet to another with minimum Delta-v requirements involves injecting it into an elliptical orbit around the Sun, called a Hohmann transfer orbit. The spacecraft travels along a segment of the elliptical path that resembles a spiral track between the orbits of the two planets, and requires no further thrust along its journey. On arrival at its target object it may use gravity alone to enter its final orbit, or it may require a burst of rocket thrust in the opposite direction – usually accomplished by simply turning the spacecraft around in space and firing the motor – before it can achieve a stable orbit.

Below: In February 2018 the SpaceX Falcon Heavy rocket demonstrated its power by putting a Tesla Roadster in a transfer orbit



> "Burning fuel allows the engine to utilise not only chemical energy, but also kinetic energy"

'WEIGHING' THE MILKY WAY

Astronomers have managed to measure the mass of our home galaxy in unprecedented detail, potentially solving some cosmological riddles

Reported by Lee Cavendish

The Milky Way is comprised of gas, dust, planets, stars, black holes and, of course, the ever-elusive dark matter. For decades astronomers have been trying to pin down the mass of our home galaxy to a good degree of accuracy, with past results varying from 500 billion-times the mass of our Sun – also known as a solar mass – to 3 trillion solar masses. This variation comes down to the difficulty in measuring the amount of dark matter that resides in our galactic home. Recently, two heavyweights in the space observatory industry teamed up to take on the task: the European Space Agency (ESA)'s Gaia satellite and NASA/ESA's Hubble Space Telescope.

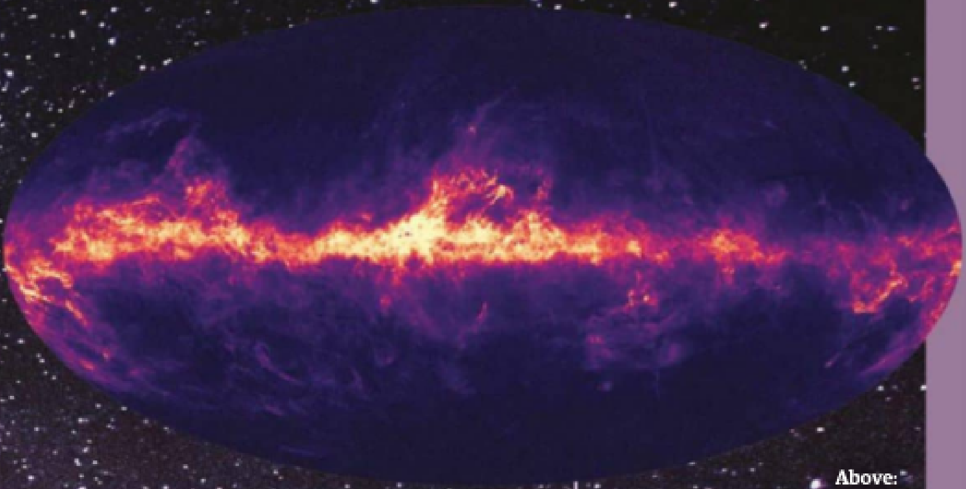
The observations taken by these two space telescopes have led astronomers to believe that the Milky Way is an astounding 1.5 trillion solar masses. What's even more shocking is that only a small percentage of this mass is contributed by the 200 billion known stars that reside in our galaxy, and the 4-million-solar-mass supermassive black hole at the centre, known as Sagittarius A*.

"We want to know the mass of the Milky Way more accurately so that we can put it into a cosmological context and compare it to simulations of galaxies in the evolving universe," says Roeland van der Marel of the Space Telescope Science Institute (STScI) in Baltimore, Maryland, US. "Not knowing the precise mass of the Milky Way presents a problem for a lot of cosmological questions."

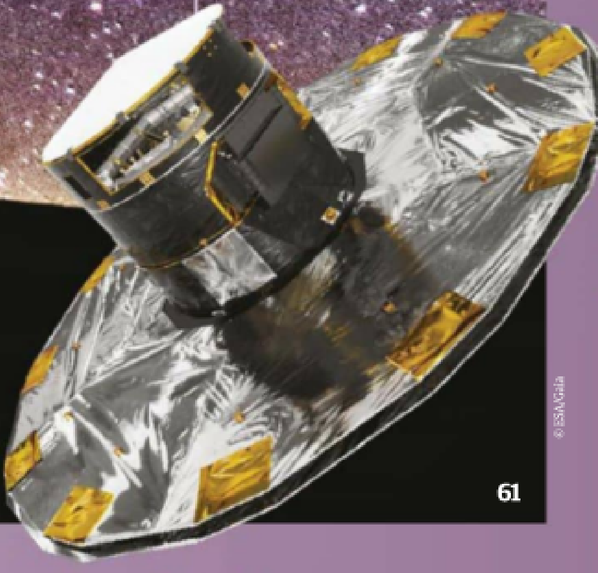
Hubble and Gaia pooled their data to create a three-dimensional map of the night sky and more accurately track the movement of globular star clusters that orbit the Milky Way. Globular clusters contain an incredibly old population of stars; some can be dated back to just a few hundred million years after the universe began, also known as the Big Bang. Although we cannot observe dark matter directly, it can be measured indirectly by the gravitational effect it has on these surrounding globular star clusters. Astronomers can tell how much an object weighs by how fast a satellite orbits it, but it requires a comprehensive study of many stellar objects in order to accurately determine an accepted figure.

Over a ten-year period the duo watched the movements of 46 star clusters – 36 by Gaia, 12 by Hubble. Gaia provided a detailed 3D map of astronomical objects' motions up to 65,000 light years away, with Hubble providing a smaller field of view, but data on clusters up to 130,000 light years away. This collaborative effort has been key in determining how much material we can see in our Milky Way, as well as material we cannot see, like dark matter.

> "We want to know the mass of the Milky Way more accurately so that we can put it into a cosmological context"

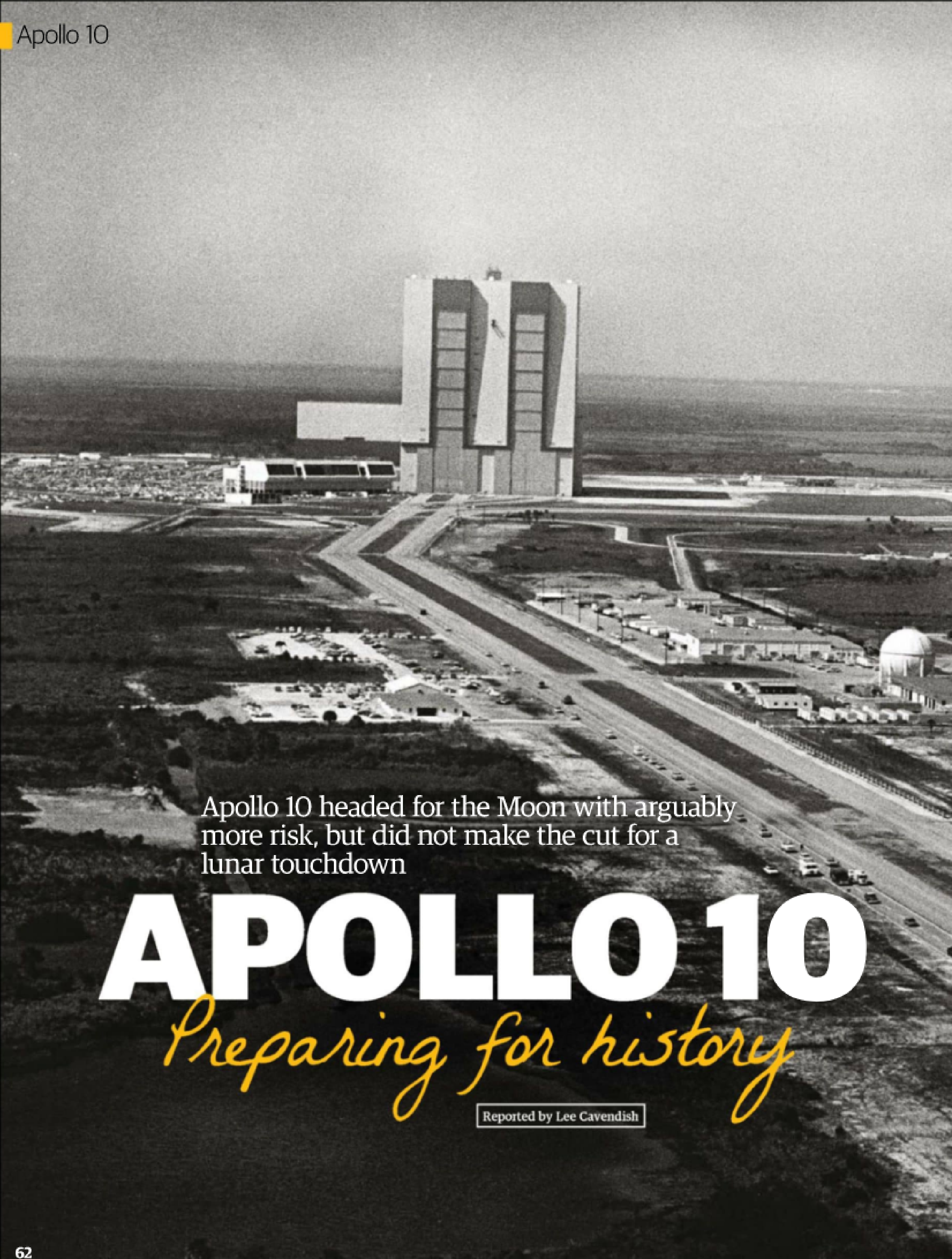


Above:
Gaia's view of the interstellar dust that fills our Milky Way galaxy



Right:
The Gaia space observatory launched in 2013

© ESA/Gaia



Apollo 10 headed for the Moon with arguably more risk, but did not make the cut for a lunar touchdown

APOLLO 10

Preparing for history

Reported by Lee Cavendish

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Issue 88 of **All About Space** told the story of Apollo 9 as it saw its 50th anniversary. Just a few months after the Apollo 9 mission, on 18 May 1969, was the launch of Apollo 10. This mission saw three of NASA's finest perform the 'rehearsal' for the Apollo 11 mission - they left Earth, went to the Moon and made a Lunar Module descent, but didn't actually make the historic touchdown. The Apollo 10 mission put everything into place so that Apollo 11 could live on in history books.

The trio of cosmic adventurers consisted of commander Thomas Stafford, Lunar Module pilot Eugene Cernan and Command Module pilot John Young. These three were no amateurs in spaceflight: it was Stafford's third, Young's third and Cernan's second spaceflight, and it wouldn't be their last. Stafford went on to be commander of the US-Soviet Apollo-Soyuz Test Project, and Young and Cernan later revisited the Moon as part of the Apollo 16 and 17 missions respectively.

On the afternoon of 18 May the three NASA astronauts boarded a Saturn V rocket at Launch Complex 39B of the Kennedy Space Center in Florida. At 4:49pm UTC (12:49pm EDT), the Saturn V rocket was launched and the mission had begun - practice for the 'big time'. After launch the Command Module, nicknamed 'Charlie Brown', and the Lunar Module, 'Snoopy' - famous characters from the comic strip *Peanuts* - all wrapped up in

The crew

Eugene A. Cernan
Lunar Module pilot
Before Apollo 10 Eugene Cernan flew on the Gemini 9A mission, and afterwards he became commander of the last manned mission to the Moon, Apollo 17.

John W. Young
Command Module pilot
John Young had the longest astronautic career of any astronaut, and became the first person to fly on six missions – Gemini 3 and 10, Apollo 10 and 16 and STS-1 and 9. He was the ninth man to walk on the Moon.

Thomas P. Stafford
Commander
Thomas Stafford had already been a pilot and command pilot for the missions Gemini 6A and 9A respectively. This was his first flight to the Moon, and his last, but he saw space again as commander of the Apollo-Soyuz Test Project.

Left: Back on Earth NASA employees watched progress from the Mission Operations Control Room in Houston, Texas

Left below: The Lunar Module was nicknamed 'Snoopy' after the *Peanuts* character, and he became the mission's mascot

the Command and Service Module (CSM), orbited the Earth one-and-a-half times before its trans-lunar injection. This put the CSM on course towards the Moon, a journey that hadn't been made since the Apollo 8 mission. It then detached from the third stage of the Saturn V rocket.

So far so good. The astronauts now had to wait as they journeyed 384,400 kilometres (238,900 miles) over the course of approximately three days to reach the Moon. There were tasks to do in the meantime; astronauts in space for that amount of time can't just sit around and do nothing! One thing that kept them busy was providing the first live colour-television transmissions from space. The first of these occurred only a few hours after launch, as they broadcasted the docking between Snoopy and Charlie Brown. "I had flown two flights before, and space is so beautiful. You look down at the Earth, and all we had was Hasselblad film and a little 16-millimetre [0.6-inch] camera. It was just short clips, so we said, 'We ought to be able to do better then this,'" said Thomas Stafford in an interview with *Spaceflight Insider*. "We put the colour TV on Apollo 10 about a week before we launched, and we had more prime colour TV time than there was on Apollo 11." Throughout the mission 19 colour television transmissions were made, totalling almost six hours of stunning visuals that people on Earth had the pleasure of seeing in real-time.

On 21 May 1969 the Apollo 10 crew had finally reached their destination and entered into an orbit around the Moon, flying approximately 110 kilometres (69 miles) over its surface. This returned the first colour-television images of the Moon's surface to Earth. After orbital insertion around the Moon it was finally time to test the most important aspect of the mission: the lunar descent. This operation is what would take humans down to the Moon's surface – though they wouldn't land yet.

© NASA, SpoonGraphics

The aims of Apollo 10

1 To demonstrate all support facilities are up to standard for a lunar mission

2 Evaluate the Lunar Module's performance during a descent

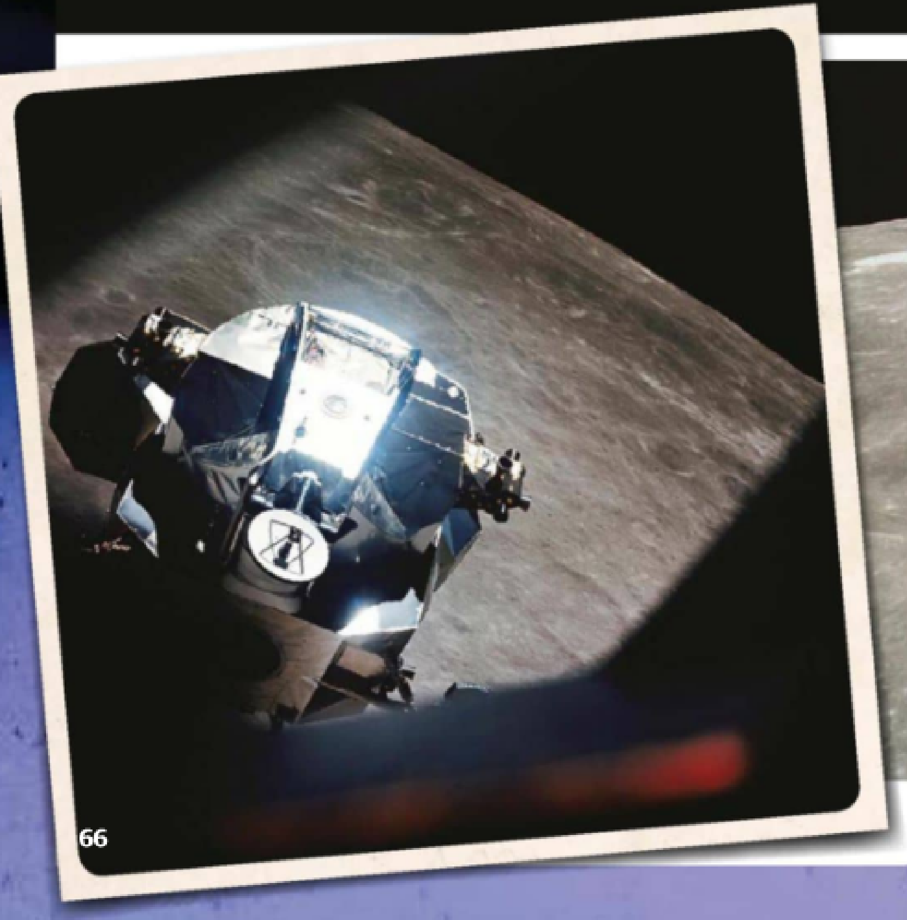
3 Perform lunar landmark tracking, particularly the Sea of Tranquillity

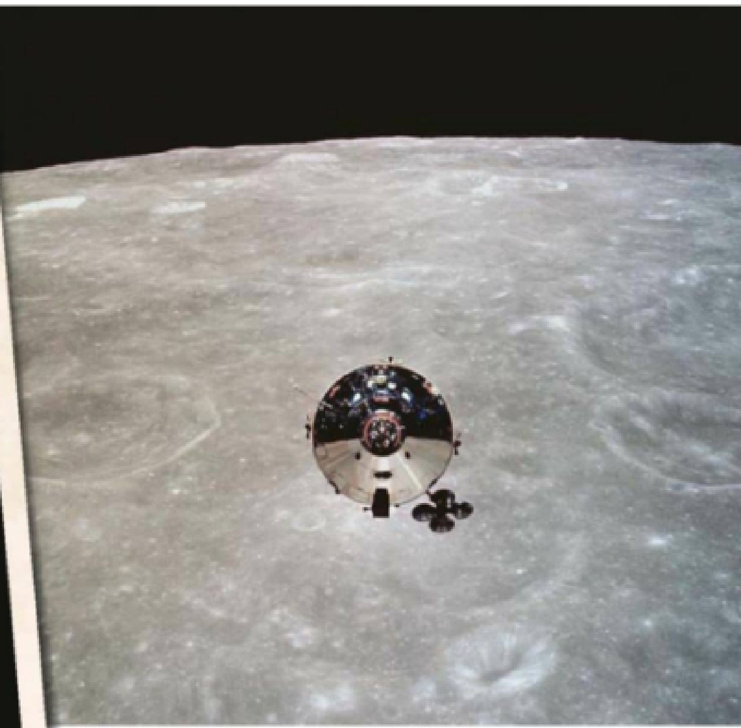
Left: Only Apollo 8 had witnessed Earth in all its glory before Apollo 10

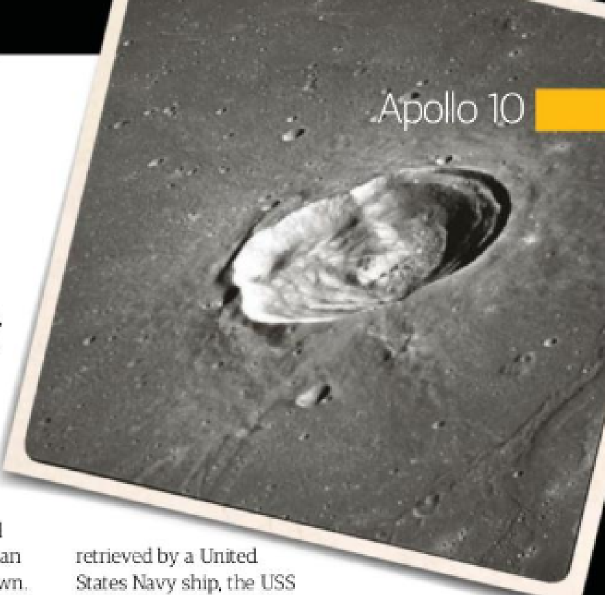
Bottom left: The Lunar Module, Snoopy, rendezvoused with the Command Module, Charlie Brown, after its close encounter with the Moon

Bottom right: Charlie Brown was photographed from Snoopy soon after separation

> "When you go to the Moon and you watch the Earth, you see something very strange in it, something very familiar" **Eugene Cernan**







Stafford and Cernan took their places in the Lunar Module ready for descent, but what was stopping these two men from becoming the ones in the history books and making the first touchdown on the lunar surface? At this point the Lunar Module was too heavy for a touchdown, and the crew needed additional training if they were to perform one. For two out of the three Apollo 10 astronauts, their time would come eventually.

A peculiar noise was soon heard by the astronauts as Stafford and Cernan separated from Young on the farside of the Moon. In the transcripts and recordings, finally released in 2008, the high-pitched sound becomes apparent and brings on an exchange between the astronauts trying to understand what it could be. It begins with Cernan saying: "That music even sounds outer-spacy, doesn't it? You hear that? That whistling sound?" This occurred on their fifth day in space, and it's obvious that this wasn't something they'd heard before. Michael Collins also noted a whistling sound while on the Apollo 11 mission. After some investigation it was discovered to be interference between the VHF radios on the two different spacecraft.

Continuing with their mission, the priority was testing the lunar descent procedure that would take Neil Armstrong and Buzz Aldrin to the Sea of Tranquillity. The descent was successful, taking Stafford and Cernan just 14.5 kilometres (nine miles) above the surface; then the closest any human had gotten to another celestial body. The Moon was tantalisingly close, and everything was seemingly running well with no major complications. But this changed as they ejected the Lunar Module's ascent pod from the descent stage. "I had all the switches set instinctively, as we will do. Tom reached over and changed positions with the guidance switch, because he knew it had to be changed to X, but I had already changed it to X," recalled Cernan on a Discovery Channel series called *Rocket Science*. "And so when it fired it was on a primary guidance system [as opposed to the abort guidance system], and a primary guidance system didn't know where to tell it to go, so we did separate, and spun out of control.

"I remember seeing a lunar horizon go by in different directions about 18 times in some 15 seconds. Tom took it back from the computer, got it under control; we gave it back to the abort guidance system. We got the burn on time and rendezvoused and everything turned out all right." This was a close call. What Stafford and Cernan didn't know at the time was that Snoopy was two seconds away from crashing into the surface of the Moon. The mission could have ended in disaster, and who knows what ramifications that would have had for the Apollo 11 mission. The fact that this was all broadcast live also meant that the public could have just witnessed a terrible event, but the astronauts regained control. Luckily the only bad result was Stafford yelling some rather understandable profanity on an open channel to the world!

All in all the mission was successful, and that story did not come to light until at least 40 years later. To unknowing ears the mission was smooth from start to finish, and no one knew for a long time that Cernan and Stafford came within two seconds of crashing into the lunar surface. However, there were aspects that were tested that would prove vital for the Apollo 11 mission, as Cernan explained: "We also checked out the landing radar on that mission and found out it had been programmed improperly. Had that happened on Apollo 11 they would not have landed. So we found out some interesting things on Apollo 10."

With half the mission done, the next objective was to make it back to Earth and land safely, which meant plucking Stafford and Cernan out from their ascent and back into Charlie Brown. On the 16th orbit of the Moon, Young rendezvoused with Snoopy, and their next 15 orbits were spent lunar landmark tracking and putting their Hasselblad cameras to good use. Afterwards Apollo 10 entered its trans-Earth trajectory, starting the trio on their three-day journey back home.

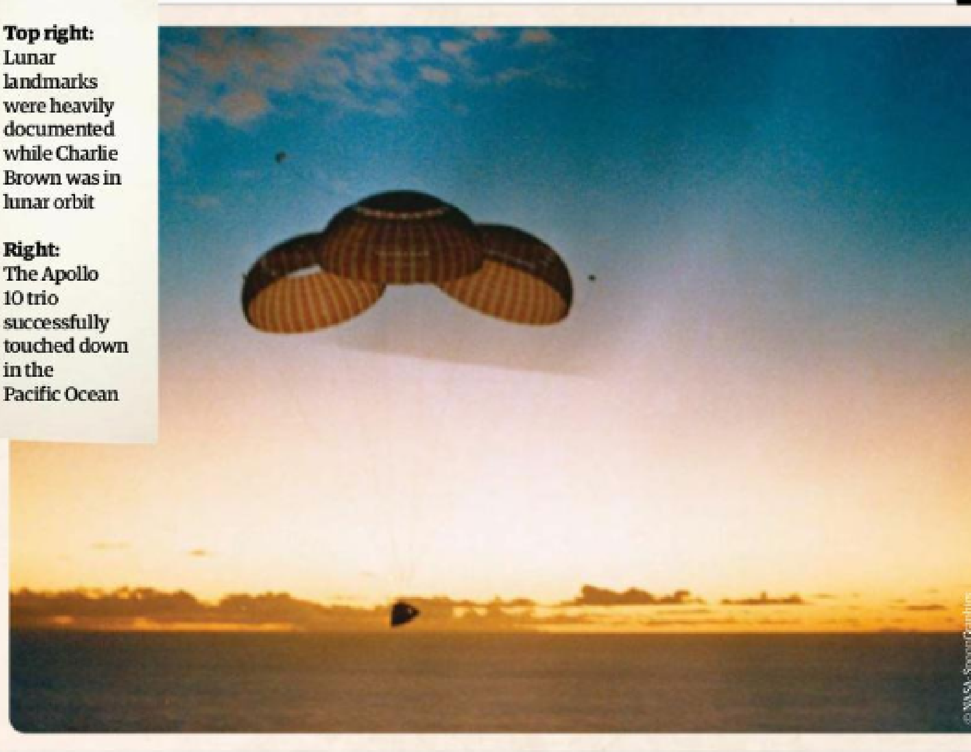
Apollo 10 would make it back to Earth and safely re-enter its atmosphere on 26 May 1969. This was the final hurdle, and 15 minutes before re-entry Charlie Brown was separated from the rest of the Service Module to begin its descent. During re-entry astronauts have to deal with terrifying speeds as they plummet down to the sea. Apollo 10 was even scarier – it actually holds the record for the top speed achieved by a manned spacecraft, going 39,897 kilometres (24,791 miles) per hour. This was much to Stafford's delight, as he previously stated in the same interview: "I always loved to fly. I wanted to be a fighter pilot and I wanted to fly the latest things to go higher and faster. I finally did go faster with Apollo 10."

Charlie Brown splashed down in the Pacific Ocean at 4:52pm UTC (12:52pm EDT) and was retrieved by a United States Navy ship, the USS Princeton. This concluded what would turn out to be a successful, important and frankly underrated mission in terms of the whole success of the Apollo program. But there is a philosophical side of going to the Moon; it is not just to test technologies and satisfy humankind's need to explore as many frontiers as possible.

Space travel can be an extremely moving experience for the individual. Cernan explained this extremely poetically: "When you go to the Moon and you watch the Earth evolve in front of you, you see something very strange in it, something very familiar. You're not flying around the Earth anymore. You're not flying through sunrises and sunsets. Without even rolling your eyeballs, you're looking across oceans and continents. You're watching as the Sun rises on one side of the world and sets on the other side all in the same instance. You're looking at a blackness beyond your perception that envelops the Earth. The infinity of time, the infinity of space, the endlessness of it all. I'm not sure what it is, but I'm sure it exists because I saw it with my own eyes."

Top right: Lunar landmarks were heavily documented while Charlie Brown was in lunar orbit

Right: The Apollo 10 trio successfully touched down in the Pacific Ocean



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Instant Expert

Retrograde motion explained

Our expert explains why some celestial objects appear to take the unusual route of travelling backwards in the night sky

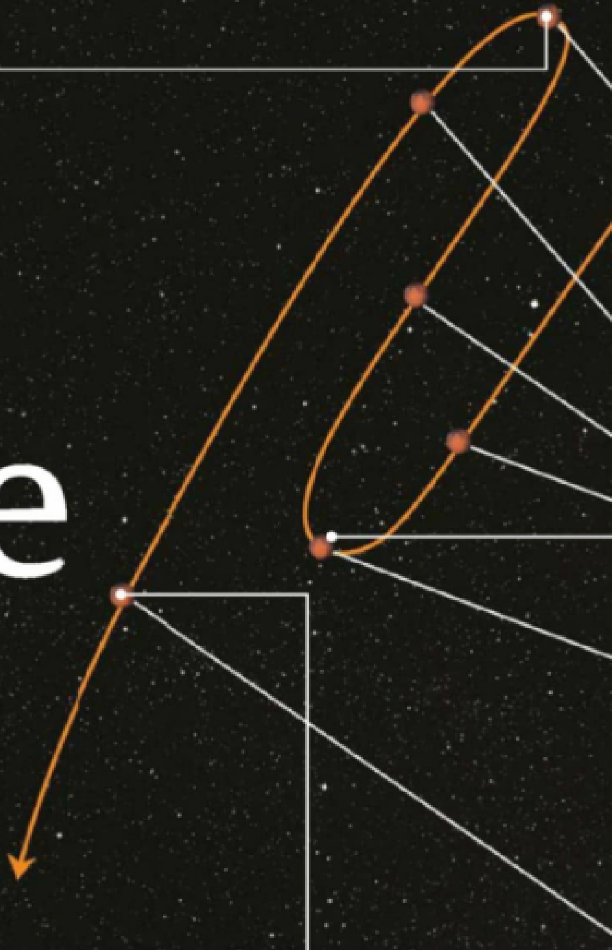
For thousands of years, humans have watched the stars to amuse ourselves, tell time and find our way. Four key observations were likely made early in astronomical research. First, the Sun rises in the east and sets in the west. Or, at the very least, a direction can be defined by the motion of the Sun. Second, most stars rise in the east and set in the west. Third, some stars, visualised as constellations, appear and disappear from the night sky at fixed times of year. Fourth, there are other stars that do not appear and disappear at fixed times of year, and sometimes even move from west to east – backwards relative to the typical motion of most stars.

These exceptional stars are now known to us as planets, and their backward motion is called 'retrograde motion', from the Latin for walking backwards. But this retrograde motion is an illusion created by the Earth and the other planets all orbiting the Sun like runners on a track.

I used to run cross-country races on a course where the skyline of a city was in the distance [Belmont Plateau, Philadelphia, United States]. At a certain point in the course, the runners would pass in front of the skyline. On the rare occasion I was about to catch another runner, they would appear to me on one side of the skyline, but if I passed them on the inside, and was unwise enough to look back, they would appear to be moving backwards relative to the skyline.

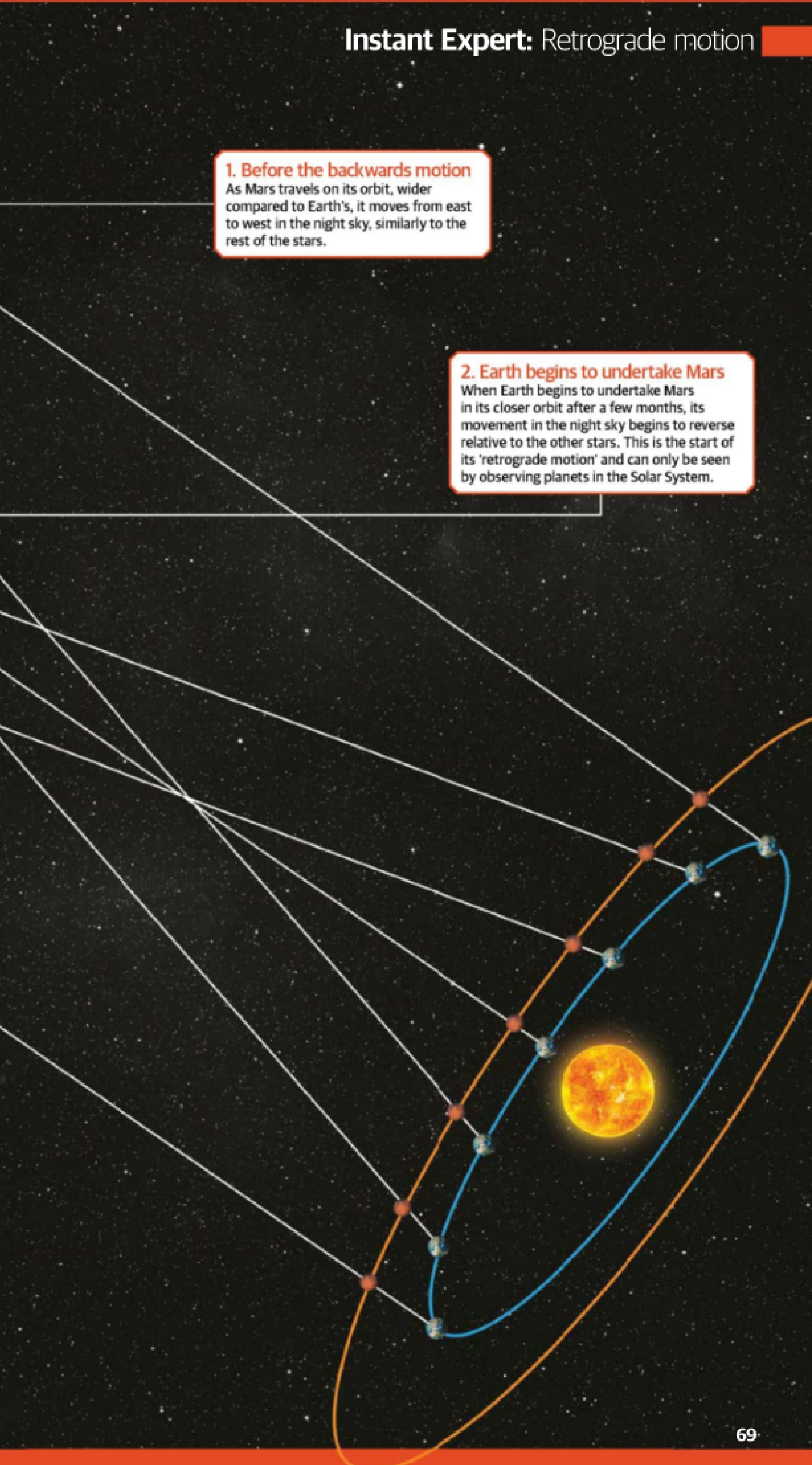
By using constellations as if they were a distant city skyline to measure relative motions of the other planets, we observe apparent retrograde motion each time the Earth passes a planet in an orbit further from the Sun – Mars, for example – or is passed by a planet in an orbit closer to the Sun, like Mercury.

> "Retrograde motion is an illusion created by the Earth and the other planets all orbiting the Sun"



3. After months of Mars moving slower
After a couple more months Mars has undoubtedly gone back on itself in the night sky. This is because Earth has undertaken Mars in its closer orbit to the Sun, and that makes the Red Planet move unusually to the rest of the stars in the night sky.

4. Resuming 'regular' motion
After the undertaking has finished, Mars will continue on its direct motion, moving from east to west again until the next time the Sun, Earth and Mars align once again to exhibit retrograde motion.



1. Before the backwards motion

As Mars travels on its orbit, wider compared to Earth's, it moves from east to west in the night sky, similarly to the rest of the stars.

2. Earth begins to undertake Mars

When Earth begins to undertake Mars in its closer orbit after a few months, its movement in the night sky begins to reverse relative to the other stars. This is the start of its 'retrograde motion' and can only be seen by observing planets in the Solar System.

BIO

Dr Nicholas Heavens

Heavens is a research assistant professor at Hampton University's Center for Atmospheric Sciences, Virginia, United States. His work includes understanding the atmosphere and weather on Mars, which means he has to make sure he keeps track of it.

SPACE EXPLORATION

What are the aims of the Deep Space Gateway?

The Deep Space Gateway is an initiative which is under discussion at the moment. It's in the early concept phases of how this thing will come together between the partners who have worked together on the International Space Station. That includes the European Space Agency, NASA, the Canadian Space Agency, the Japanese agency JAXA and the Russian space agency Roscosmos.

The idea is that as we look to move beyond low-Earth orbit, where we operate at the moment with the International Space Station, we would work together to build what we call the Deep Space Gateway. This would be a platform where humans could live and work that is in the vicinity of the Moon, so not on the lunar surface, but in orbit around the Moon.

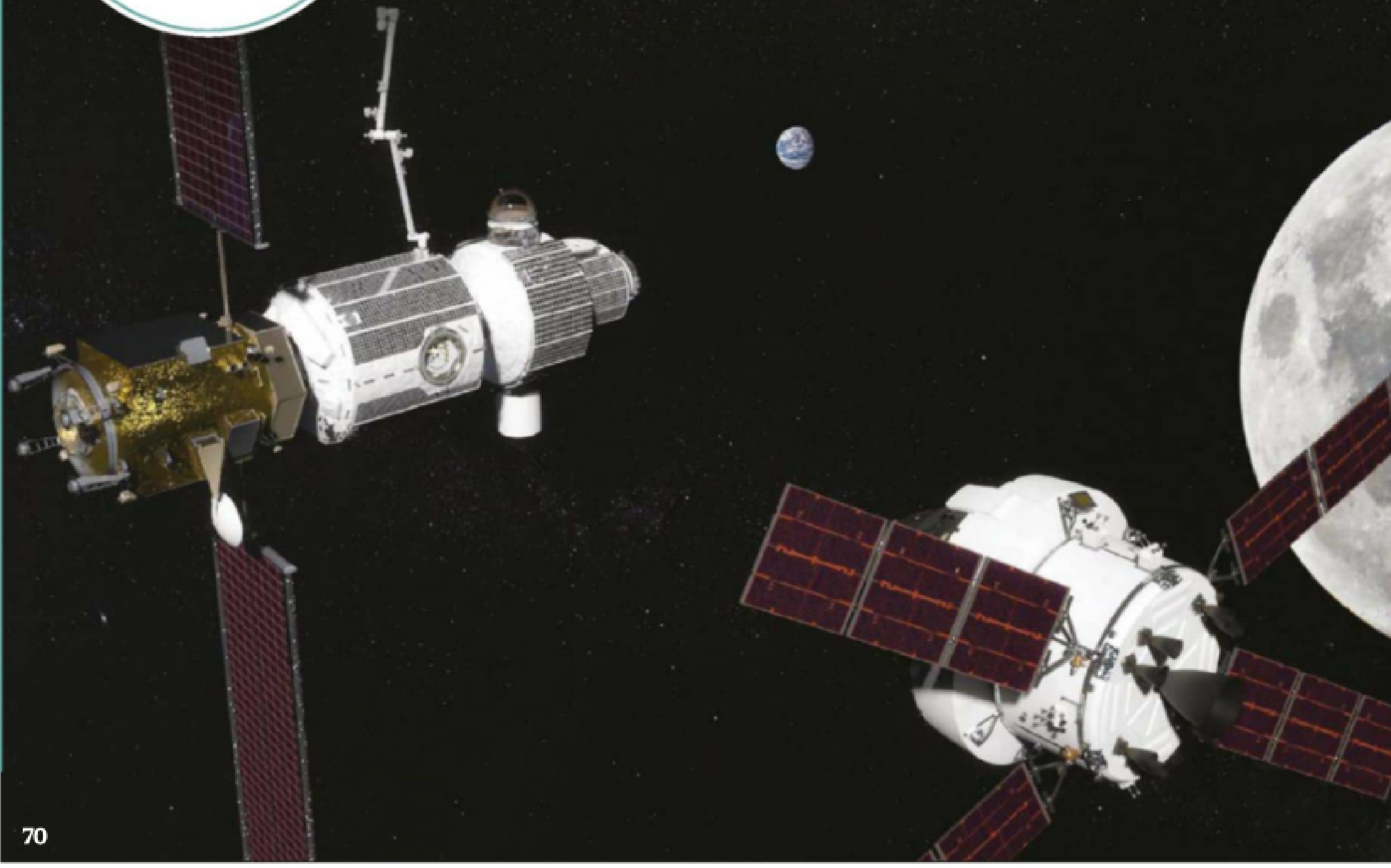
This is a place where we would learn what it would mean to live and work away from the Earth. We would test technologies and do research as it becomes the first element in an infrastructure to allow exploration to the surface of the Moon, onwards to Mars and maybe to other destinations in the future. So it's really the first step in a sustainable architecture for exploration for humans.

James Carpenter is the human and robotic exploration strategy officer at the ESA

"We would learn what it would mean to live and work away from the Earth"

Did you know?

The Indian Space Research Organisation's Chandrayaan-1 Moon probe found water in the soil of the Moon which could be used as rocket fuel.



Below: The Deep Space Gateway will be a collaborative effort between worldwide organisations

ASTROPHYSICS

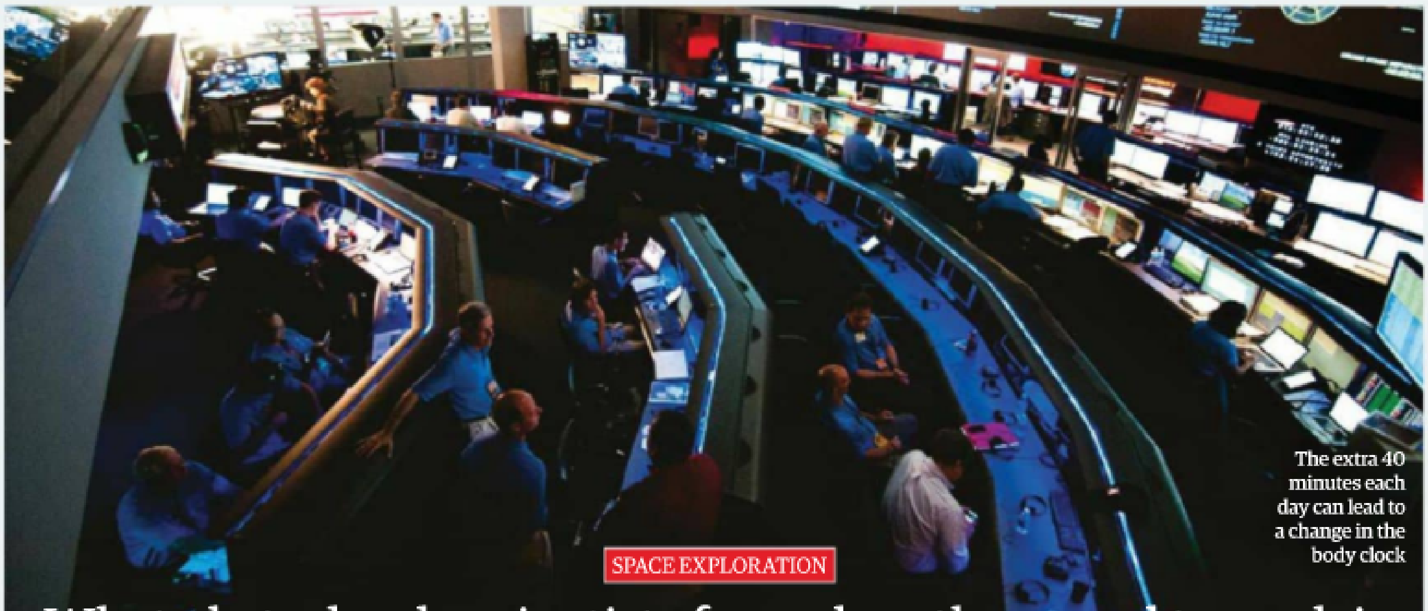
What exists outside our observable cosmos?

There are some questions that science just can't answer. This is one of them. Humanity, in our three-dimensional (plus time) reality, is confined to this universe. We can't experience what is beyond through any means known to science. Imagine life on the surface of a vast balloon. If all you know is the balloon's surface, you can identify no centre on that surface. You can't see what is inside that surface or external to that surface. While observational science doesn't allow us to get to an answer from here, theorists have put forward a variety of ideas.

One possibility is that there is a vast quantum foam from which bubble universes regularly come into and go out of existence. Some scientists point to the seeming fine-tuning of our universe, which makes life possible, as evidence that we are in one of many universes of many different configurations. This probability-based argument doesn't make multiple universes real, however, and it is just as possible that there is nothing at all beyond our universe.

Pamela Gay is senior education and communication specialist and senior scientist for the Planetary Science Institute, US

Other bubble universes could be surrounding our own



The extra 40 minutes each day can lead to a change in the body clock

SPACE EXPLORATION

What obstacles do scientists face when they need to work in Martian days instead of Earth days?

When you're switching your body clock to Mars time it's important to consider the impact it has on you and your family. For scientists and engineers coming from other parts of the country and the rest of the world, they have a different set of challenges. They'll be living in either townhouses or rented apartments with roommates who are also likely on Mars time, so there's not such a sense of inconveniencing those around you. However, they are gone for three months or more from their families.

But whether living at home with families or away from them, all of us had to face the challenge that the Sun rises above the Earth at a certain time, and you can't block out everything. The errands and daily activities that you have to do are still there, so you have to learn where the 24-hour fuelling stations, diners and grocery stores are, but there's still a lot you can't do. It's a challenge to conduct the rest of your Earth life while your work life is on Mars time.

Nagin Cox is a spacecraft engineer at NASA's Jet Propulsion Laboratory (JPL) and part of the Curiosity team

© NASA/JPL-Caltech, Adrian Mann

Did you know?

Most stars form in binary pairs because they spin so quickly as they form that their surfaces reach escape velocity before they finish collapsing, creating a pair.

They are nicknamed Tatooine-like planets after the planet from the *Star Wars* films

> "Some scientists point to the seeming fine-tuning of our universe as evidence that we are in one of many universes"

SPACE EXPLORATION

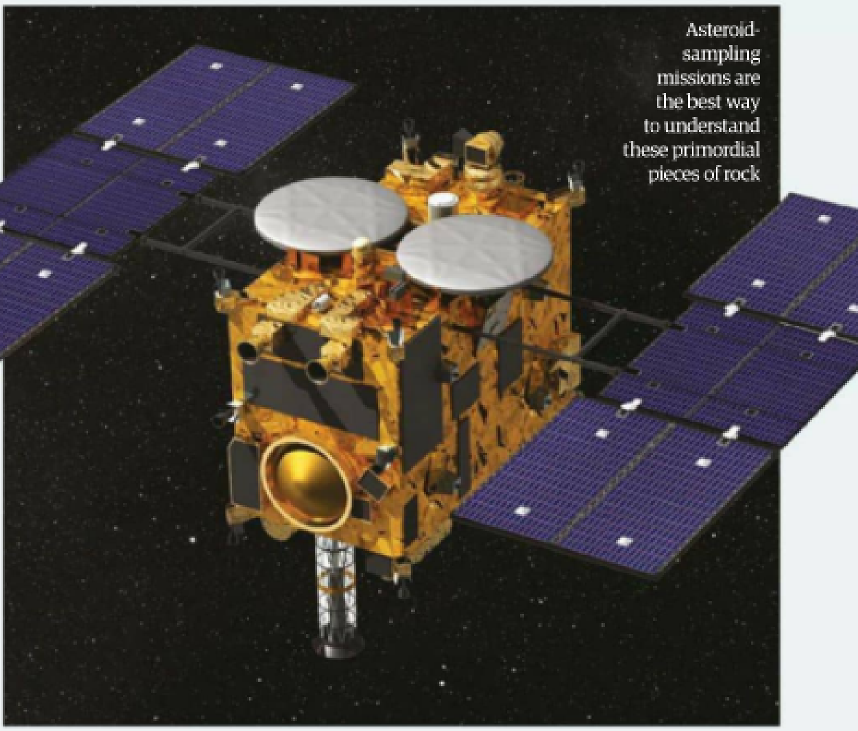
Is it difficult to retrieve an asteroid sample?

There are mainly two hardships. Firstly, the asteroid is far from Earth. Hayabusa2 had to land on the asteroid Ryugu, which was 300 million kilometres (190 million miles) away. Therefore it is impossible to steer the spacecraft for landing from Earth. Instead the spacecraft has to think by itself to safely land on the ground and retrieve the sample – a high level of autonomy is mandatory.

Secondly, asteroids are so small that we cannot see their appearance unless we get there. The difficulty of sampling from asteroids is that we have to design a spacecraft and sampling mechanism way before we see them. The spacecraft has to be designed for an unknown asteroid environment, no matter how hard or bumpy the surface is, and no matter how strong the gravity is.

Hayabusa2 successfully landed on Ryugu on 22 February 2019. Ryugu is covered by numerous rocks, and there was only a six-metre (16-foot) diameter safe area for the landing. This was quite challenging for the spacecraft. It's like throwing a tiny ball from London to make it fly though the hole of a needle in Tokyo.

Yuichi Tsuda is the project manager of JAXA's Hayabusa2 mission



Asteroid-sampling missions are the best way to understand these primordial pieces of rock

© NASA/ESA; Tobias Roetsch; Orlando Florin Rosu / Alamy Stock Photo

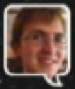
EXOPLANETS

Would it be possible to survive on a planet around a double-star system?

Tatooine-like planets, planets orbiting around double or binary stars – also known as circumbinary planets (CBPs) – are no longer just science fiction. The Kepler spacecraft has so far observed about ten transiting CBPs. Here we focus on circumbinary-type planets that move around the centre of mass of the double-star system in a relatively wide orbit.

The first requirement for survival on a CBP is that the planet remains dynamically stable. Gravitational perturbations from the binary can destabilise the circumbinary orbit. If this happens then the CBP is likely ejected from the system, or it could even collide with one of the stars. Both are not favourable scenarios for survivability. Secondly, if we agree to need liquid water for survival, and ideally a breathable atmosphere, the CBP should neither be too close nor too far from the binary.

Even if we manage to find a habitable CBP it is not guaranteed to stay habitable indefinitely. Over timescales of billions of years the binary stars – assuming they are similar to the Sun – will evolve. In later stages the stars will lose a lot of mass when they evolve to white dwarfs. The mass loss could unbind the CBP, hurdling it into the darkness of space. If not, the dim light from the white dwarfs would usher in an indefinite ice age. We are fortunate to be living on a planet that (for now) is very accommodating to life.



Adrian Hamers is a postdoctoral fellow at the Institute for Advanced Study in Princeton, New Jersey, US

ASTROPHYSICS

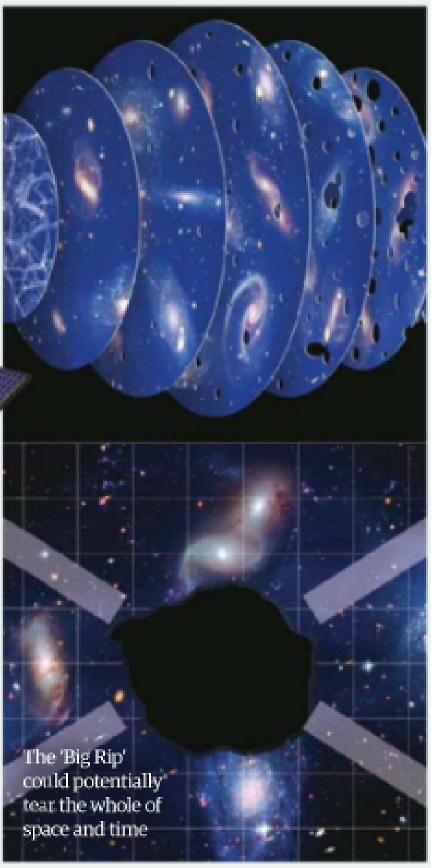
Could there be lifeforms made out of antimatter?

According to theory, it should be possible. If we consider lifeforms to be symphonies of atoms, molecules and larger biological structures interacting, we expect that the forces which govern the behaviour of these things would be the same for bodies made entirely of matter as for equivalent bodies of antimatter.

However, these theories also suggest that our universe should be half matter and half antimatter – a prediction that is readily discounted by observing that pretty much everything we see is made out of matter. Researchers are actively addressing this discrepancy by testing the assumption that matter and antimatter interactions are exactly the same by, for example, comparing the colours of antihydrogen and hydrogen.

No significant difference has been found, but it is still early days as far as direct measurements on antimatter are concerned. If even a slight difference were found we would need to update our theories, and then perhaps we would conclude something else about the possibility of antimatter lifeforms.

William Bertsche is a lecturer at the University of Manchester, UK



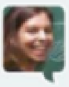
The 'Big Rip' could potentially tear the whole of space and time

ASTROPHYSICS

Given the universe's acceleration, could it end in a Big Rip?

The universe is most likely infinite, but we still talk about the size of the cosmos. What we really mean is the size or limits of the observable universe. We are currently living in a universe in accelerated expansion, which means that objects in the universe recede away from us with a speed that grows with the distance. Even if we waited an infinite amount of time we would never be able to observe beyond some distance because objects very far away from us are receding away from us so fast that neither light, nor gravitational waves nor any other type of information emitted by those objects would ever be able to reach us.

We know that the expansion of the universe is accelerating, but if the acceleration was itself speeding up, then the size of the observable universe would shrink and there would be a time where the observable universe would be so small that we wouldn't even be able to see our neighbouring galaxies. When the size of the observable universe is even smaller than the minimal length we can conceive, this would correspond to a Big Rip, possibly tearing apart the whole structure of space and time.



Claudia de Rham is professor of theoretical physics at Imperial College London, UK

STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

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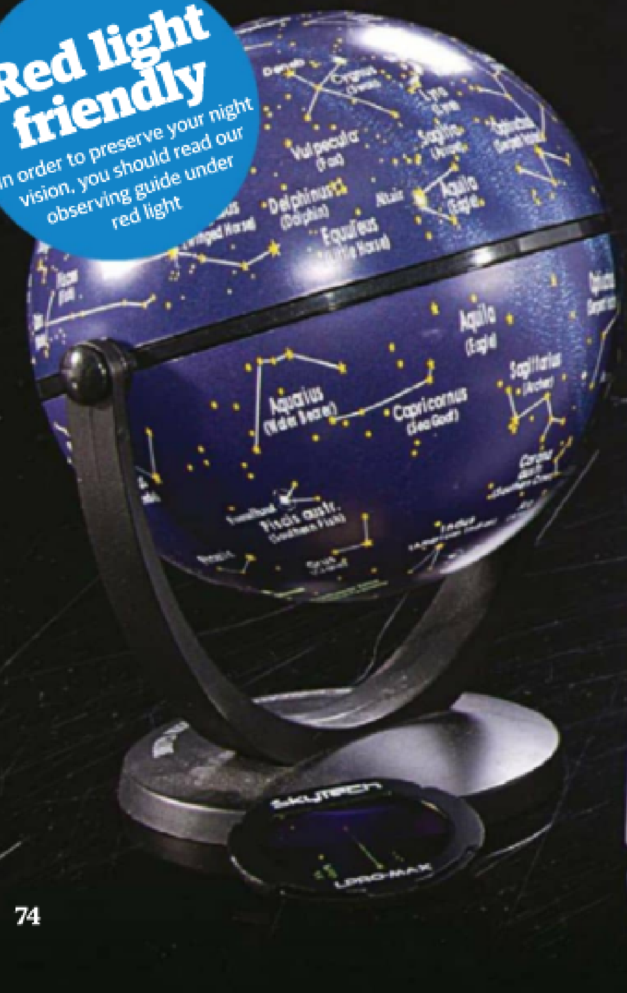
Red light friendly

In order to preserve your night vision, you should read our observing guide under red light



What's in the sky?

© NASA

25 APR
Conjunction between the Moon and Saturn in Sagittarius

25 APR
The Moon and Saturn make a close approach, passing within 0°22' of each other in Sagittarius

28 APR
The Alpha Scorpiids reach their peak of five meteors per hour

6 MAY
The Eta Aquariids reach their peak of 40 meteors per hour

8 MAY
Conjunction between the Moon and Mars in Taurus

11 MAY
The Moon and Messier 44 will make a close approach, passing within 0°19' of each other

© Miguel Garcia

© Tunc Tezel

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

© NASA/JPL

25 APR 🔭

The Moon and Pluto make a close approach within 0°04' of each other in Sagittarius

© NASA

© NASA/JPL

8 MAY 👁

The Moon and Mars make a close approach, passing within 3°12' of each other in Taurus

13 MAY 🔭

The Alpha Scorpiids reach their peak of five meteors per hour

20 MAY 👁

Conjunction between the Moon and Jupiter in Ophiuchus

20 MAY 👁

The Moon and Jupiter make a close approach, passing within 1°40' of each other in Ophiuchus

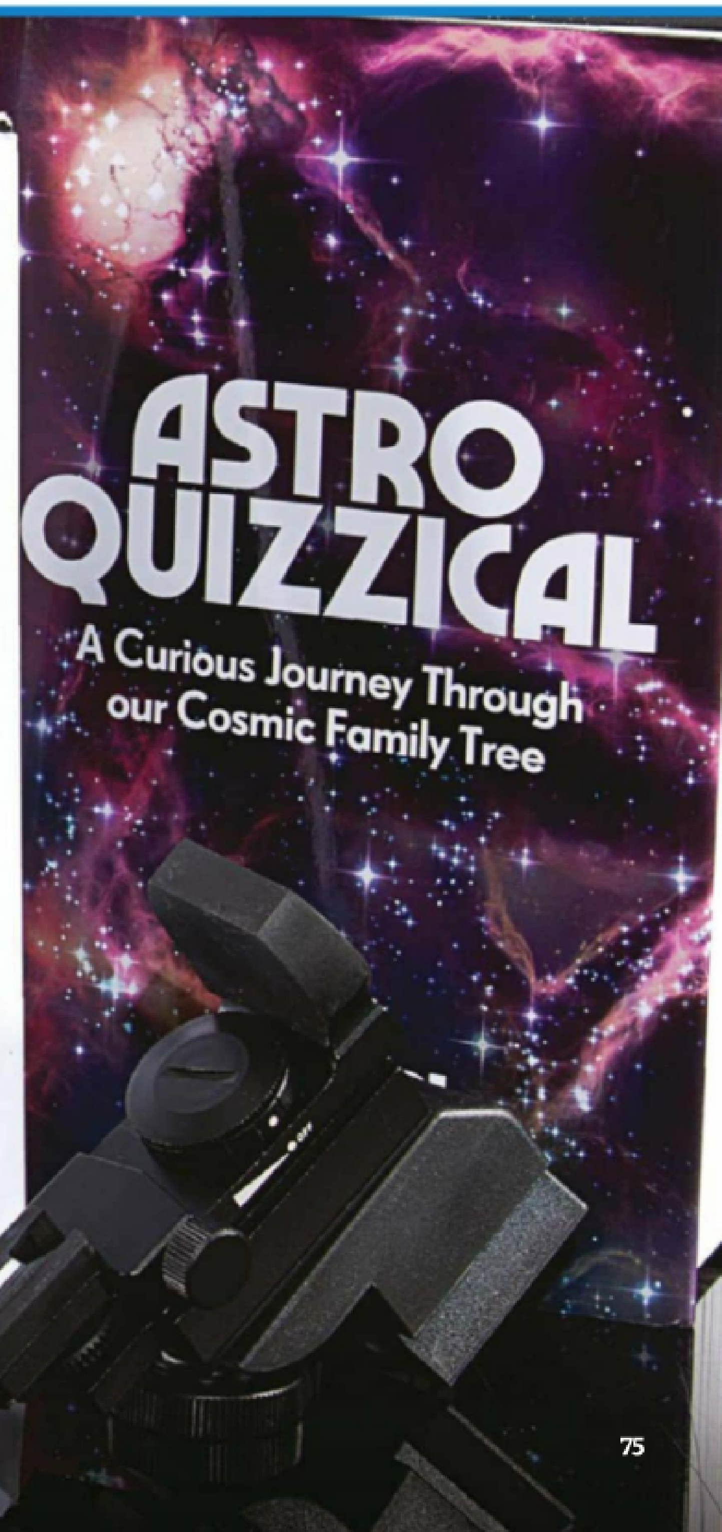
22 MAY 👁

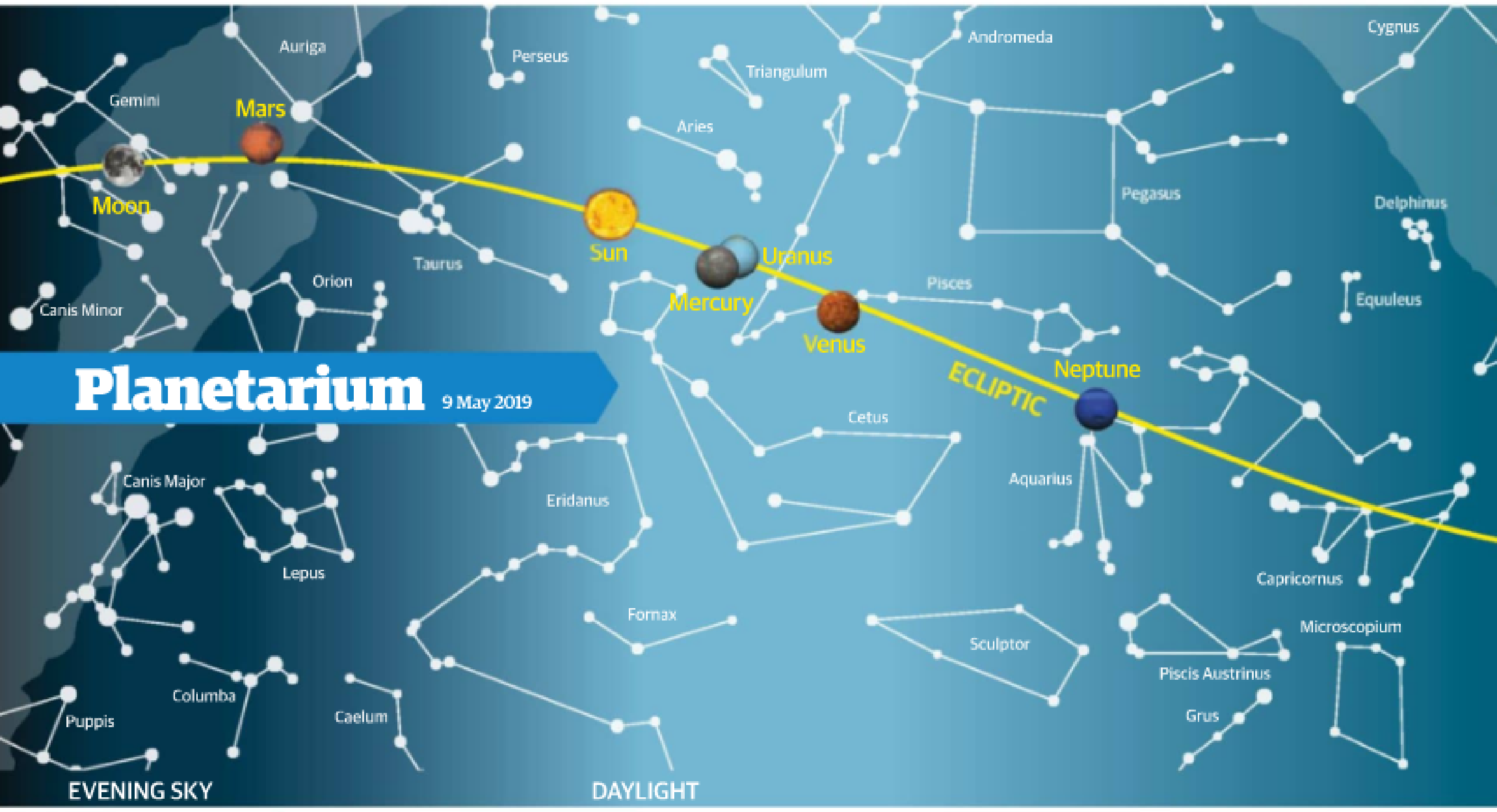
Conjunction between the Moon and Saturn in Sagittarius

22 MAY 👁

The Moon and Saturn make a close approach within 0°31 of each other in Sagittarius

- 👁 Naked eye
- 🔭 Binoculars
- 🔭 Small telescope
- 🔭 Medium telescope
- 🔭 Large telescope



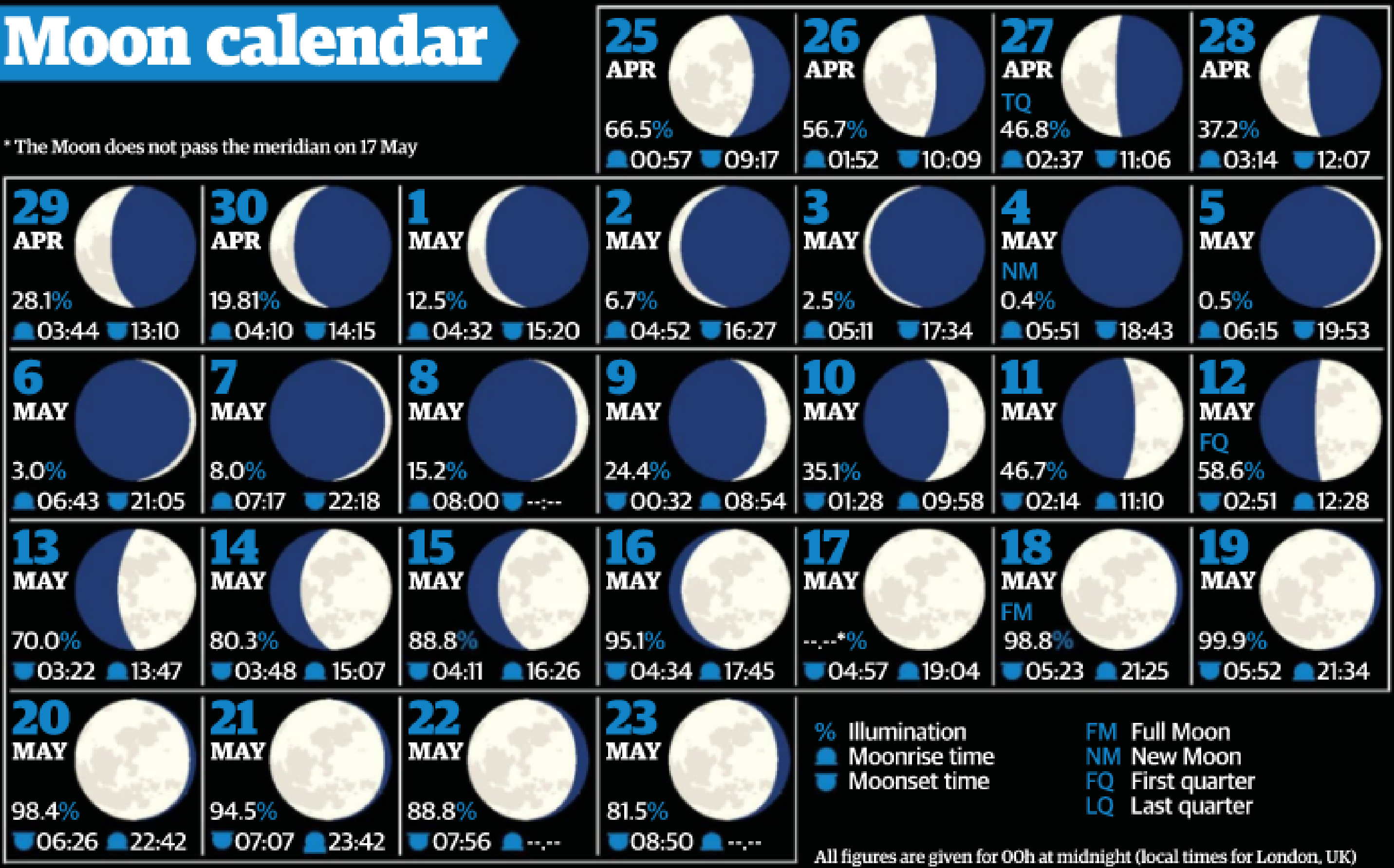


Planetarium

9 May 2019

Moon calendar

* The Moon does not pass the meridian on 17 May

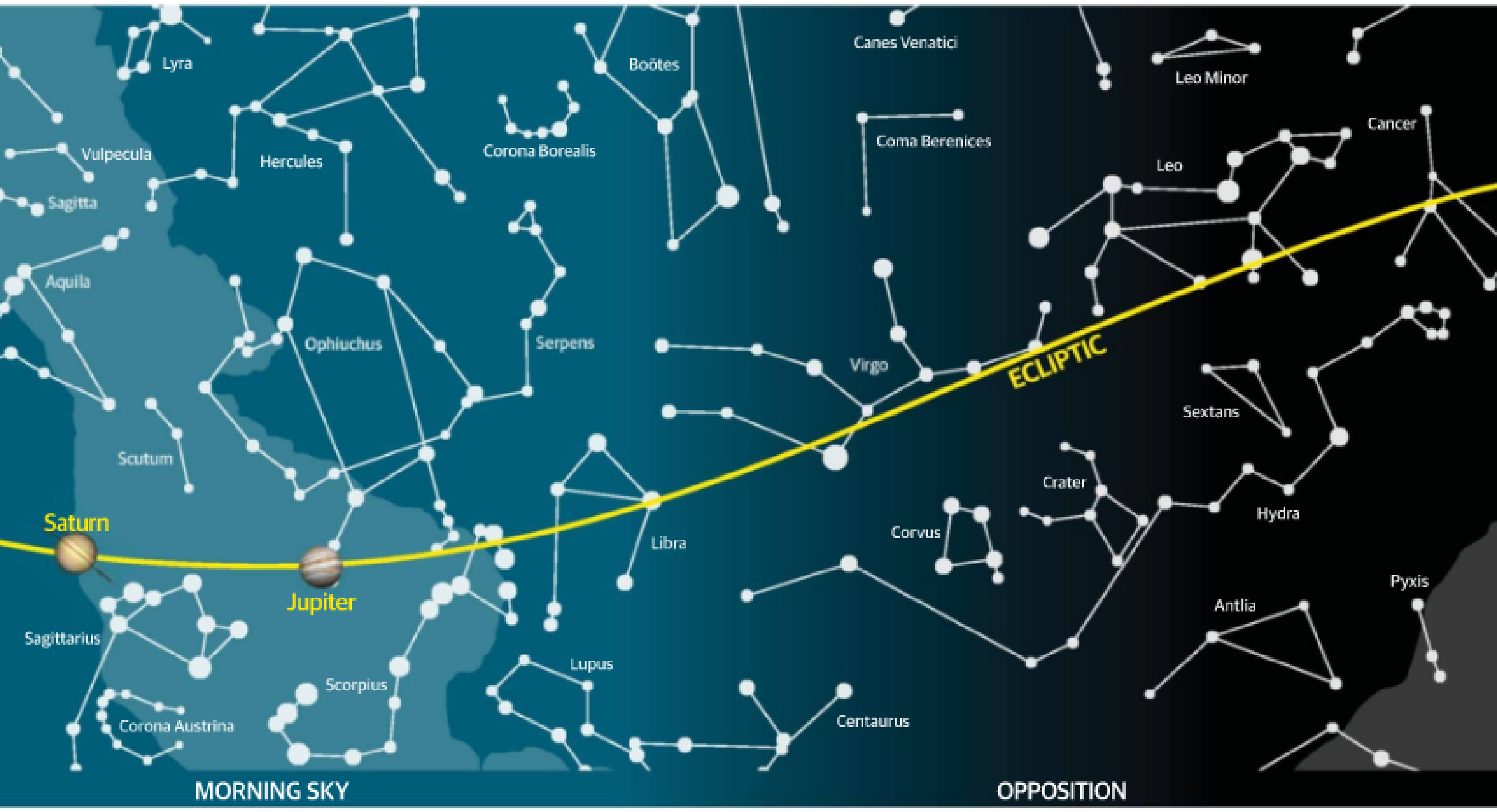


Date	Phase	Illumination	Time	Time
25 APR		66.5%	◓ 00:57	◒ 09:17
26 APR		56.7%	◓ 01:52	◒ 10:09
27 APR	TQ	46.8%	◓ 02:37	◒ 11:06
28 APR		37.2%	◓ 03:14	◒ 12:07
29 APR		28.1%	◓ 03:44	◒ 13:10
30 APR		19.81%	◓ 04:10	◒ 14:15
1 MAY		12.5%	◓ 04:32	◒ 15:20
2 MAY		6.7%	◓ 04:52	◒ 16:27
3 MAY		2.5%	◓ 05:11	◒ 17:34
4 MAY	NM	0.4%	◓ 05:51	◒ 18:43
5 MAY		0.5%	◓ 06:15	◒ 19:53
6 MAY		3.0%	◓ 06:43	◒ 21:05
7 MAY		8.0%	◓ 07:17	◒ 22:18
8 MAY		15.2%	◓ 08:00	◒ --:--
9 MAY		24.4%	◒ 00:32	◓ 08:54
10 MAY		35.1%	◒ 01:28	◓ 09:58
11 MAY		46.7%	◒ 02:14	◓ 11:10
12 MAY	FQ	58.6%	◒ 02:51	◓ 12:28
13 MAY		70.0%	◒ 03:22	◓ 13:47
14 MAY		80.3%	◒ 03:48	◓ 15:07
15 MAY		88.8%	◒ 04:11	◓ 16:26
16 MAY		95.1%	◒ 04:34	◓ 17:45
17 MAY		--.--*%	◒ 04:57	◓ 19:04
18 MAY	FM	98.8%	◒ 05:23	◓ 21:25
19 MAY		99.9%	◒ 05:52	◓ 21:34
20 MAY		98.4%	◒ 06:26	◓ 22:42
21 MAY		94.5%	◒ 07:07	◓ 23:42
22 MAY		88.8%	◒ 07:56	◓ --.--
23 MAY		81.5%	◒ 08:50	◓ --.--

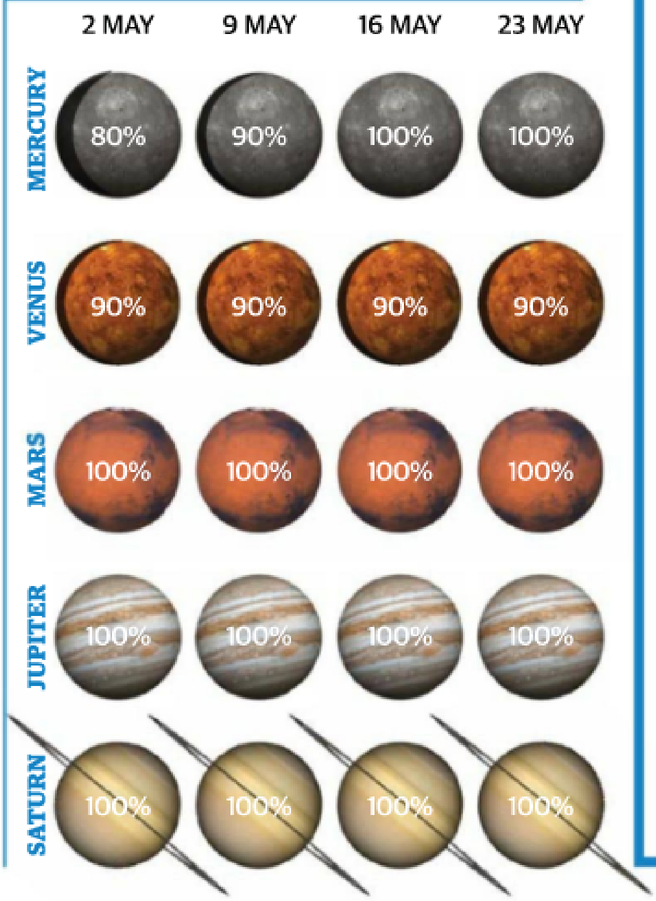
% Illumination
◓ Moonrise time
◒ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	2 MAY	9 MAY	16 MAY	23 MAY
MERCURY	80%	90%	100%	100%
VENUS	90%	90%	90%	90%
MARS	100%	100%	100%	100%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

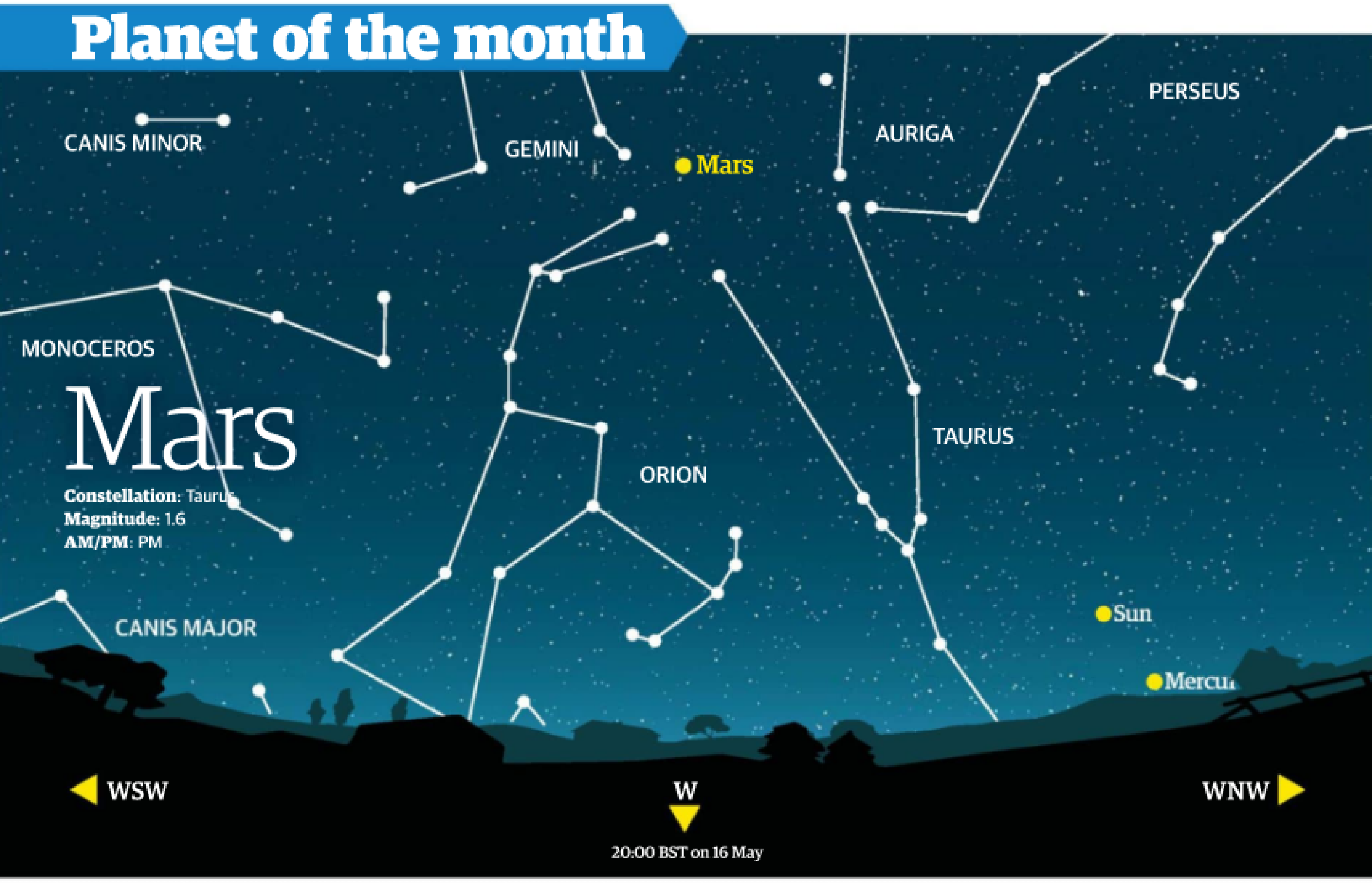
All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	25 Apr	00h 41m 50s	+01° 32' 23"	Cetus	-0.1	05:18	17:41
	02 May	01h 22m 28s	+06° 04' 09"	Pisces	-0.4	05:08	18:17
	09 May	02h 09m 04s	+11° 13' 27"	Aries	-0.8	05:00	19:03
	16 May	03h 02m 52s	+16° 34' 57"	Aries	-1.6	04:55	19:59
	23 May	04h 03m 56s	+21° 21' 19"	Aries	-2.3	04:58	21:03
VENUS	25 Apr	00h 20m 49s	+00° 30' 53"	Pisces	-3.9	05:02	17:15
	02 May	00h 52m 09s	+03° 47' 12"	Pisces	-3.9	04:49	17:35
	09 May	01h 23m 43s	+07° 00' 52"	Pisces	-3.9	04:37	17:55
	16 May	01h 55m 41s	+10° 07' 54"	Pisces	-3.9	04:25	18:16
	23 May	02h 28m 17s	+13° 04' 21"	Aries	-3.9	04:13	18:37
MARS	25 Apr	04h 58m 46s	+23° 44' 45"	Taurus	1.6	07:26	00:09
	02 May	05h 18m 39s	+24° 10' 36"	Taurus	1.6	07:15	00:04
	09 May	05h 38m 34s	+24° 26' 52"	Taurus	1.7	07:06	23:55
	16 May	05h 58m 29s	+24° 33' 31"	Taurus	1.7	06:57	23:48
	23 May	06h18m 20s	+24° 30' 35"	Gemini	1.7	06:50	23:40
JUPITER	25 Apr	17h 32m 58s	-22° 39' 25"	Ophiuchus	-2.4	00:24	08:20
	02 May	17h 31m 19s	-22° 38' 27"	Ophiuchus	-2.5	23:50	07:50
	09 May	17h 29m 05s	-22° 37' 05"	Ophiuchus	-2.5	23:20	07:21
	16 May	17h 26m 19s	-22° 35' 17"	Ophiuchus	-2.5	22:50	06:51
	23 May	17h 23m 07s	-22° 33' 03"	Ophiuchus	-2.6	22:19	06:20
SATURN	25 Apr	19h 27m 17s	-21° 31' 18"	Sagittarius	0.5	02:10	10:21
	02 May	19h 27m 22s	-21° 31' 27"	Sagittarius	0.5	01:43	09:54
	09 May	19h 27m 06s	-21° 32' 18"	Sagittarius	0.4	01:15	09:26
	16 May	19h 26m 30s	-21° 33' 53"	Sagittarius	0.4	00:47	08:57
	23 May	19h 25m 36s	-21° 36' 07"	Sagittarius	0.3	00:19	08:29

This month's planets

The God of War rules the night this May, while the King of the Solar System has a long reign in the sky

Planet of the month



Mars

Constellation: Taurus
Magnitude: 1.6
AM/PM: PM

20:00 BST on 16 May

Mars might not be the brightest planet in the sky this month – shining at magnitude 1.6 it will only be as bright as Castor in Gemini, which itself is only the 20th-brightest star in the whole sky – but there is so much going on around it.

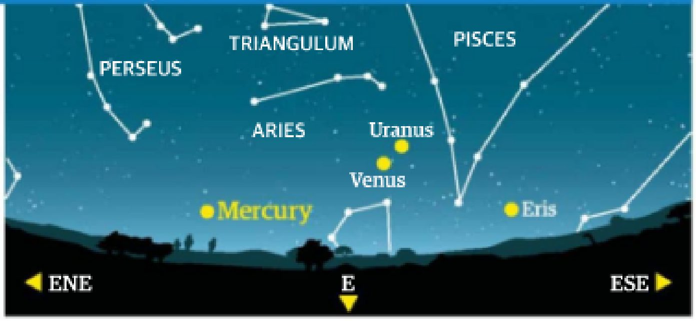
Between late-April and late-May Mars will be a modestly bright 'Evening Star' low in the western sky after sunset, looking like an extra orange 'star' between the horns of Taurus, The Bull, to the upper left of the Hyades and Pleiades star clusters. That's quite a busy area of the sky, so if you're not sure which 'star' Mars is, it will lie halfway between brighter and redder Betelgeuse in Orion and yellow-white Capella in Auriga. You'll be able to see Mars as soon as the sky begins to darken, but it will be setting around midnight so you'll only have a short window of visibility in which to observe it.

To make up for its lack of brightness, Mars will have some pretty impressive company in the sky this month. As the western sky darkens after sunset on the evening of 7 May look for a fingernail-clipping-thin crescent Moon shining directly beneath Mars, just over four degrees from it. The following evening the Moon – now a slightly fuller crescent – will be shining to the upper left of Mars, more than 11 degrees from it.

On 16 May Mars will cross the border between Taurus and Gemini. Two days later it will be shining very close to the bright star cluster M35. On the 19th Mars will actually drift through the star cluster and through binoculars or a telescope will look like an orange star embedded within it, contrasting strongly with the blue and white stars which make up the cluster. As you look at Mars shining inside the cluster on that evening it will be humbling and fascinating to think that while Mars is 350 million kilometres (217 million miles) away – so far that light from it took almost 20 minutes to reach Earth – the pinprick stars in the cluster beyond are so far away that their light set off 3,000 years ago. By the next evening Mars will have drifted free of the star cluster and will be shining a short distance to its upper left.

Mars continues to be the 'go-to' planet for scientists involved in the exploration of the Solar System with robot probes. Probes from a variety of different countries are orbiting Mars, with more planned to join them in the years ahead, and in 2020 NASA will be sending another nuclear-powered rover to explore it. When will the first humans leave bootprints in the planet's dust? Some think around the year 2035, but that may prove to be overly optimistic.

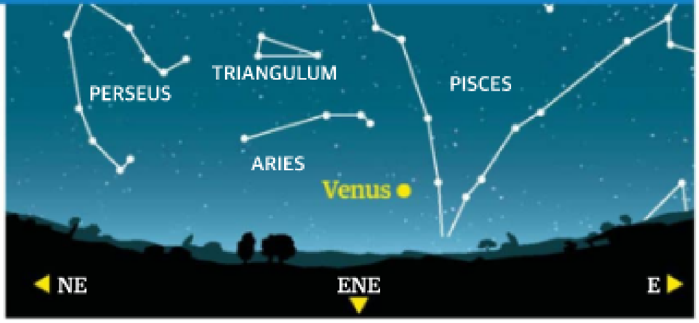
Mercury 05:30 BST on 20 May



Constellation: Cetus
Magnitude: -0.1
AM/PM: AM

Although it is often labelled 'elusive', sometimes Mercury is easily visible to the naked eye as a copper-coloured 'star', low in the western sky just after sunset or in the east just before sunrise. Unfortunately this isn't one of those times. The tiny world will be rising at around the same time as the Sun, so it will not be visible.

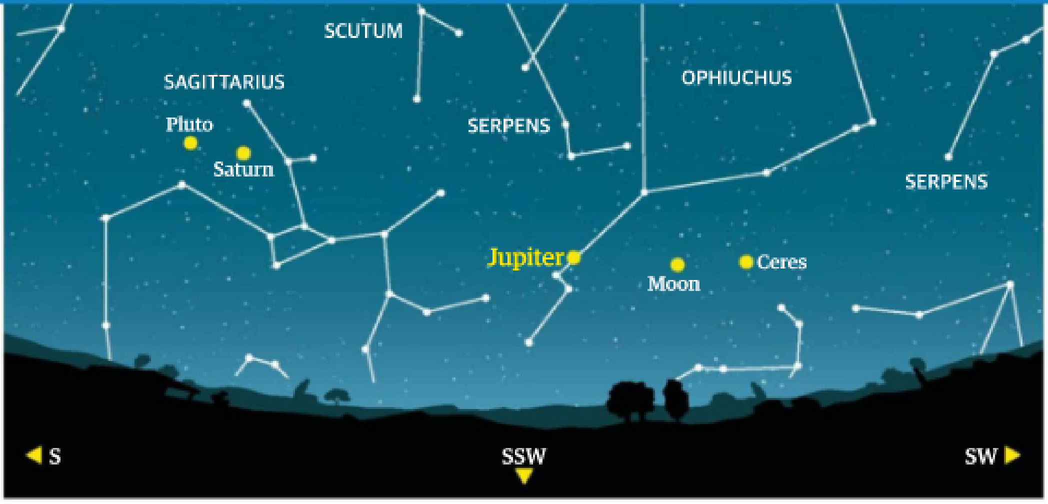
Venus 05:00 BST on 17 May



Constellation: Pisces
Magnitude: -3.9
AM/PM: AM

Technically Venus is a 'Morning Star' this month, as it rises before the Sun, and with a magnitude of -3.9 you might expect the second world out from the Sun to be a striking naked-eye object. Sadly Venus rises so shortly before the Sun that it will be overwhelmed in the Sun's glare, so will be virtually impossible to see.

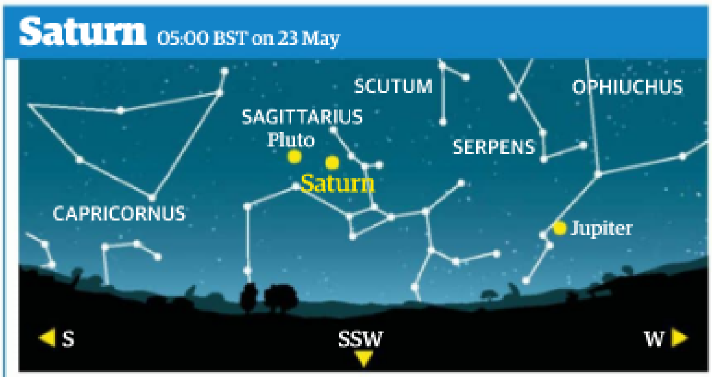
Jupiter 05:00 BST on 20 May



Constellation: Ophiuchus
Magnitude: -2.4
AM/PM: AM

Jupiter is by far the largest planet in the Solar System. So huge it could contain over a thousand Earths, it will be visible this month from the very early hours right through the night, until dawn's light washes it from the sky. At the start of our observing period it will be rising at around 1am, and by the end of May it will be rising around 11pm, giving plenty of time to enjoy the sight of it blazing low in the sky like a blue-white spark. Look out for the full Moon shining just eight degrees to Jupiter's left on the morning of 20 May, and only five degrees to the planet's left the following morning.

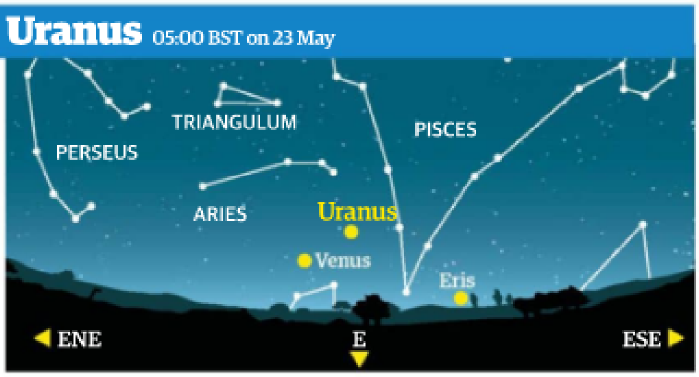
Saturn 05:00 BST on 23 May



Constellation: Sagittarius
Magnitude: 0.5
AM/PM: AM

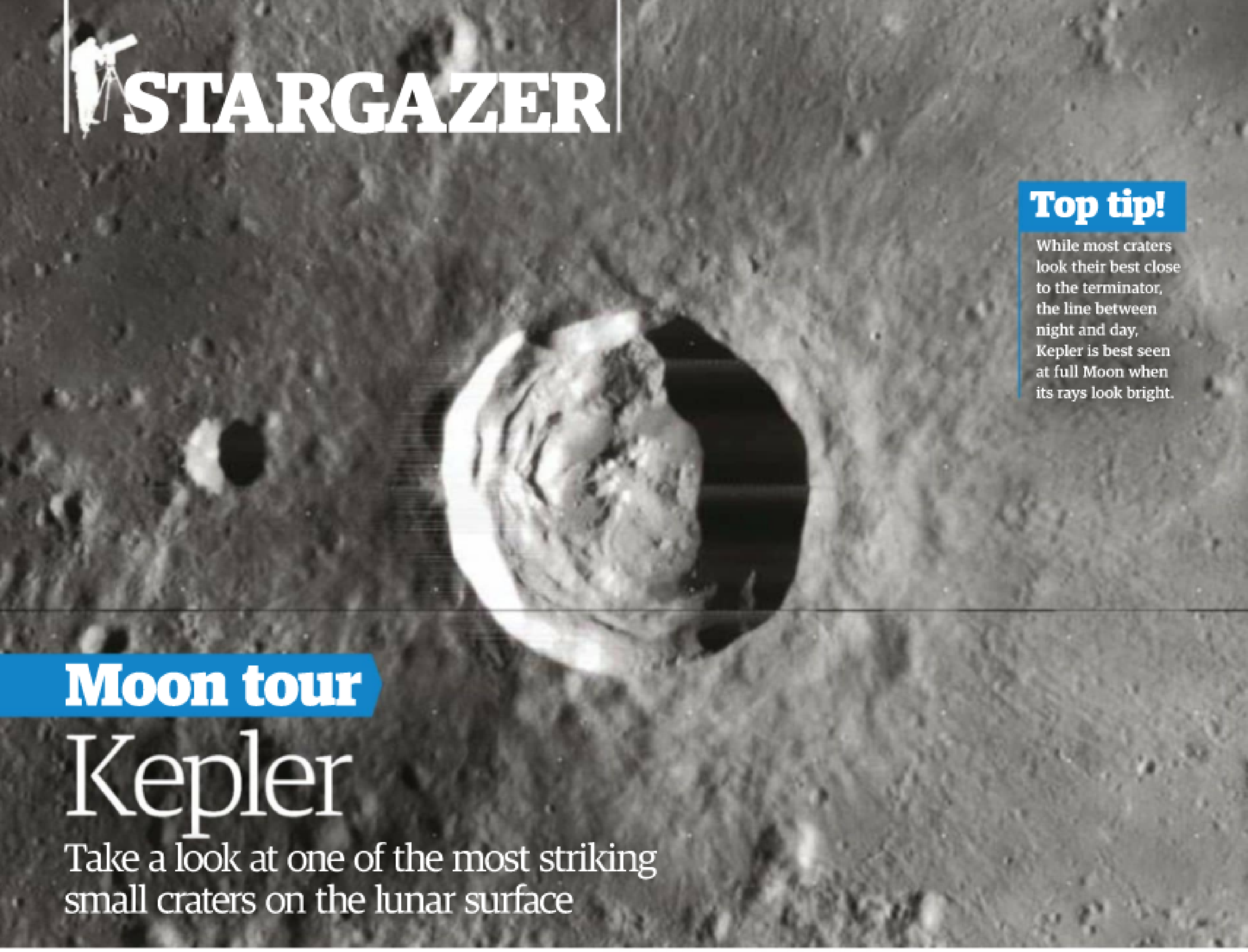
In mid-April the planet famous for its system of shining, icy rings will be rising at around 2:30am, and by the end of May will be rising before 1am, so prospects for observing it will slowly improve as the days and weeks pass. Look for the waning gibbous Moon six degrees to the upper right of Saturn before sunrise on 25 April.

Uranus 05:00 BST on 23 May



Constellation: Aries
Magnitude: 5.9
AM/PM: AM

If you want to track down this strange, dim world, you're out of luck this month because it will be too close to the Sun to be visible. In the early days of May it will pass very close to both Mercury and Venus - a gathering of worlds we'll have to enjoy using planetarium software or apps instead of our own eyes.



Top tip!

While most craters look their best close to the terminator, the line between night and day, Kepler is best seen at full Moon when its rays look bright.

Moon tour

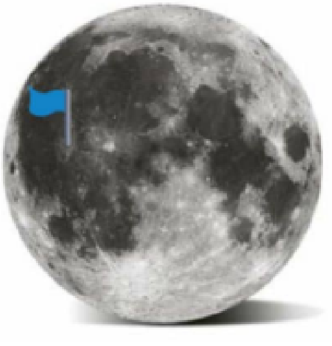
Kepler

Take a look at one of the most striking small craters on the lunar surface

Look at the full Moon through your binoculars or small telescope and once your dazzled eyes have stopped watering you will see a triangle of small, bright dots on the left-hand side of the almost blindingly bright disc, just above its centre, looking for all the world like the bright mark a trio of stones made when smashed into the ice covering a frozen pond or lake. These bright spots are craters: three of the most famous and widely observed craters on the whole of the Moon. The one in the centre is called Kepler, and it's our destination for this month's tour...

Kepler is a reasonably small crater. It is dwarfed by better-known and larger craters such as Copernicus, Tycho and Ptolemaeus, but it is very popular among veteran and novice lunar observers alike because it is the source of a splendid spray of bright rays of impact debris. In fact, the longest of the rays which spread out from Kepler reaches a distance of almost 300 kilometres (186 miles), overlapping the ray systems of other, older craters in the region. These rays look their best when the Moon is full and the Sun is blazing overhead as seen from Kepler; it is then the rays look like trails of bright-white snow splashed and sprayed across the dark-grey surface of the Moon, and look beautiful in any telescope, large or small.

Kepler is a young crater, formed in the Copernican Era - at some time in the last billion years or so - by an asteroid slamming into the region of the Moon to the west of the much larger and more impressive 'Monarch of the Moon', Copernicus. The impact blasted a hole out of the Moon's surface 32-kilometres (19.8-miles) wide and around three-kilometres (1.8-miles) deep and showered the surrounding region with a hail of tumbling debris, laying down the rays we see splashing away from it.



Through a telescope or the camera eyes of an orbiting satellite, Kepler is revealed to be slightly polygonal in shape, with high rampart walls which rise sharply on the outside and are slumped and broken up into terraces and ledges on the inside. Its floor is hummocky and uneven, with no dramatic central peak or peaks to catch the eye or the Sun's low slanting rays when the crater is close to the terminator. High magnifications show Kepler is surrounded by many smaller 'satellite' craters, formed when debris from the impact which created it spattered down on the surrounding area, pockmarking it with secondary craters. In fact, NASA's Lunar Reconnaissance Orbiter probe took an image in 2011 showing a huge boulder, 100 metres (328 feet) across, sitting on the surface not far from the crater - a piece of debris that thudded out of the sky in the aftermath of the impact.

So when can you see this fascinating and beautiful crater, formed in such a violent event, this month?

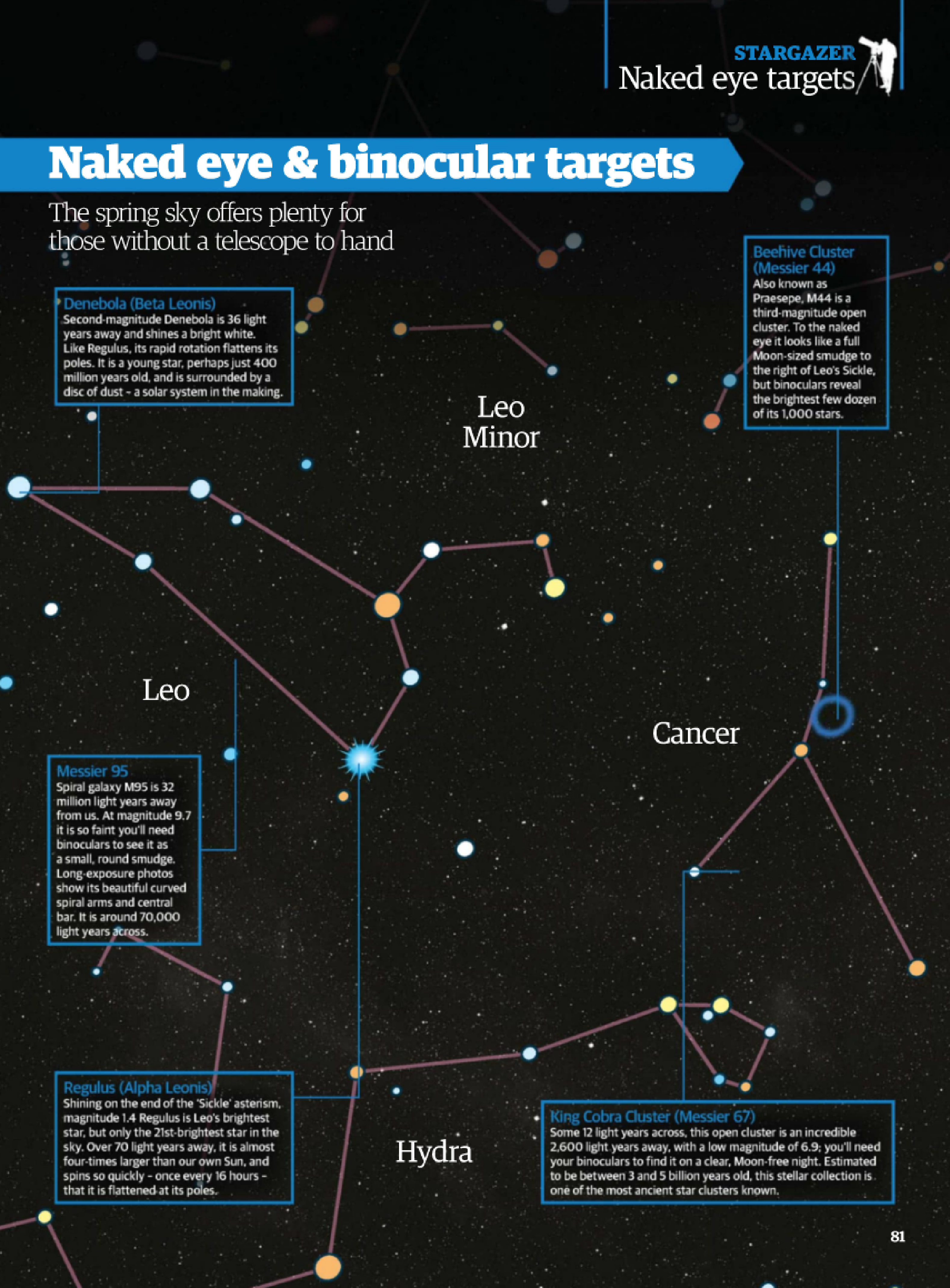
At the start of our observing period the Moon will be at its waning gibbous phase, so Kepler will be bathed in bright sunlight and easily visible, both with the naked eye and through observing instruments, with its dramatic system of rays really standing out on the surface. However, as the days pass the terminator - the line separating night from day - will relentlessly sweep towards Kepler from the east. As the Sun drops in Kepler's sky the rays will appear to fade and lose their beauty until only the pit of the crater itself is obvious - details on the surface around it and inside its walls and across its floor will be more readily visible.

By 28 April, with the terminator almost upon it, Kepler will be a fascinating sight through your favourite high-power telescope eyepiece, but a day or so later it will be lost from view as the Sun sets on it, plunging it into darkness. It will not reappear until mid-May, around the 14th, and by the time the Moon is full on the 18th it will be visible in all its glory again as a bright spot at the centre of a splash of snow-white rays.

© NASA

Naked eye & binocular targets

The spring sky offers plenty for those without a telescope to hand



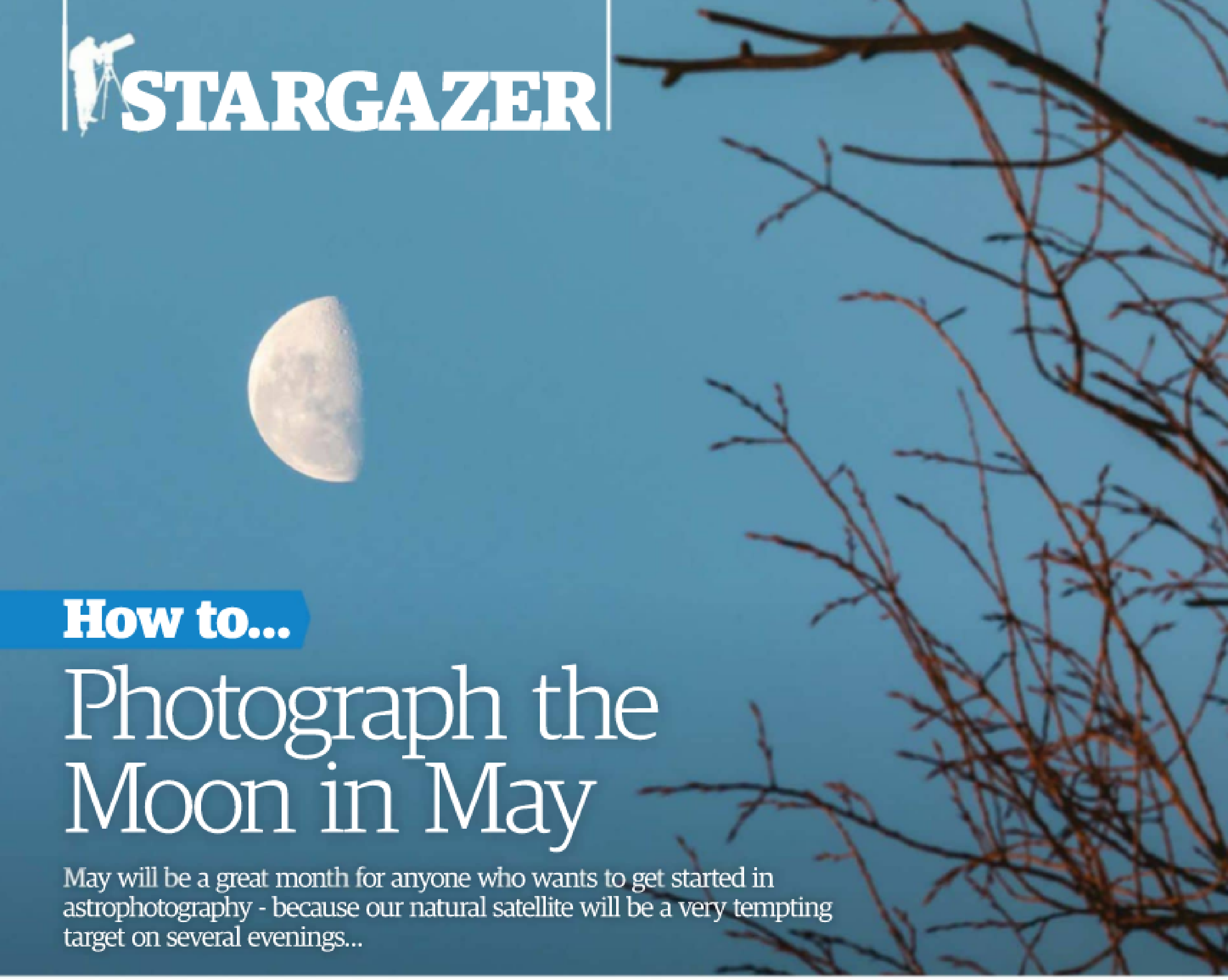
Denebola (Beta Leonis)
Second-magnitude Denebola is 36 light years away and shines a bright white. Like Regulus, its rapid rotation flattens its poles. It is a young star, perhaps just 400 million years old, and is surrounded by a disc of dust – a solar system in the making.

Beehive Cluster (Messier 44)
Also known as Praesepe, M44 is a third-magnitude open cluster. To the naked eye it looks like a full Moon-sized smudge to the right of Leo's Sickle, but binoculars reveal the brightest few dozen of its 1,000 stars.

Messier 95
Spiral galaxy M95 is 32 million light years away from us. At magnitude 9.7 it is so faint you'll need binoculars to see it as a small, round smudge. Long-exposure photos show its beautiful curved spiral arms and central bar. It is around 70,000 light years across.

Regulus (Alpha Leonis)
Shining on the end of the 'Sickle' asterism, magnitude 1.4 Regulus is Leo's brightest star, but only the 21st-brightest star in the sky. Over 70 light years away, it is almost four-times larger than our own Sun, and spins so quickly – once every 16 hours – that it is flattened at its poles.

King Cobra Cluster (Messier 67)
Some 12 light years across, this open cluster is an incredible 2,600 light years away, with a low magnitude of 6.9; you'll need your binoculars to find it on a clear, Moon-free night. Estimated to be between 3 and 5 billion years old, this stellar collection is one of the most ancient star clusters known.



How to...

Photograph the Moon in May

May will be a great month for anyone who wants to get started in astrophotography - because our natural satellite will be a very tempting target on several evenings...

You'll need:

- ✔ DSLR (Digital Single Lens Reflex) camera
- ✔ Sturdy tripod
- ✔ Cable release
- ✔ Wide-angle lens (35mm focal length or shorter)
- ✔ Zoom or telephoto lens (200mm or longer)
- ✔ Computer
- ✔ Image-processing software

Open up any copy of **All About Space** and you'll see lots of beautiful images of the night sky - astrophotographs, pictures of astronomical events and celestial objects taken by amateur astronomers. Many are the result of many hours of hard work processing images taken with very sophisticated - and very expensive - equipment by people with years of experience. But you don't need thousands of pounds worth of kit or years of experience to take lovely images - a basic DSLR camera on a tripod is enough. But how do you get started?

During May the Moon will offer beginners a great 'way in' to astrophotography. As well as being a beautiful photographic target in its own right, the Moon will have some fascinating company in the sky and offer many attractive photo opportunities too.

You'll need to have two lenses for your DSLR - a wide-angle lens and a zoom or telephoto lens. The shorter focal length your wide-angle lens is, the better; an 18 to 55mm 'kit' lens will be fine set at 18mm, but anything shorter than 35mm will do, and if you have a 10mm lens that would be perfect. A long lens with a focal length of 300mm will be fine, 200mm will do, and if you're lucky enough to have a 500mm or longer lens you'll get amazing images of the Moon's dark seas, towering ranges of jagged mountains and countless impact craters surrounded by bright splashes of debris.

To photograph these and the other events taking place in May you'll need to mount your DSLR on a tripod. The steadier and sturdier the better; any vibrations will result in blurred images. If your tripod is light, weigh it down by hanging something heavy from its centre. Also, use a cable release if you have one to reduce vibrations even further.

Set your DSLR to Manual mode, turn off the flash and set the ISO to 800, at least at first. Focusing on the Moon is tricky, as it is small and very bright in the sky, so if your camera has 'Live View' you can use that to help you. Zoom in on the Moon, making its image on your screen as large as possible, then focus on the limb. If it is too bright, reduce the exposure time until the Moon becomes dim enough to see its sharp rim clearly, then focus on that.

Tips & tricks

Avoid 'jelly-leg' tripods

If your tripod is too light, or wobbly, it won't support your camera properly during the timed exposures and your images will be blurred.

Cable release

Using even a very basic cable release to begin your exposures instead of pressing the shutter button with your finger will reduce vibrations.

Keep things sharp

When photographing the Moon sharp focus is essential. Use 'Live View' to focus on an enlarged image of the Moon if your camera has it.

There's nothing wrong with pretty pictures

Not every astrophoto has to be scientifically useful or educational. It's fine just to take images showing how beautiful an object or event was.

© Dietmar Rabich

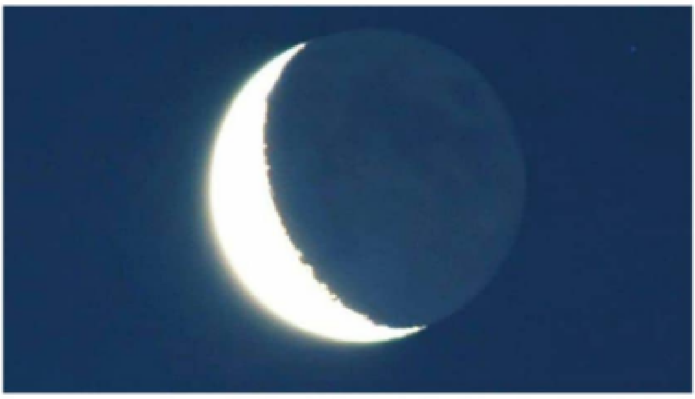
Getting the perfect shot

Keep adjusting settings until you are happy with your images

When you take your photographs, bracket the exposures - take exposures of long and short duration - until you find one which works, then stick with that. Try combinations of different exposures, apertures and ISOs until you have taken an image you like, then stick with that combination and take more. The main thing is to simply experiment - and have fun!

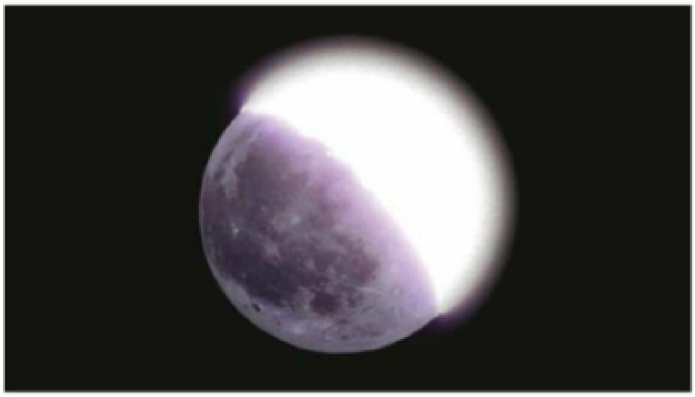
Send your photos to
space@spaceanswers.com

1 **Get the timing right**
On 7 May a very thin crescent Moon will be close to Mars. Use both your lenses to capture lovely views of the pair shining close together in the dusk.



© Ilmari Karonen

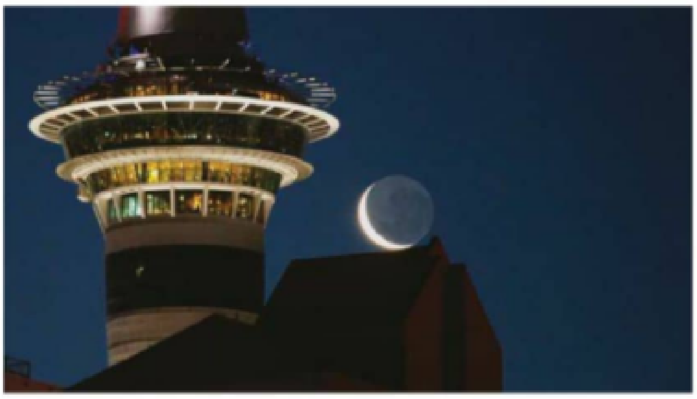
2 **Wait for Earthshine**
On 8 May use your long lens to capture the dark part of the Moon's face illuminated by the soft, subtle, lavender glow of Earthshine.



© [illegible]

3 **Pick out detail**
Your long lens will capture fascinating views of craters and mountains along the terminator when the Moon is at first quarter phase on 12 May.

4 **Wait for the 'Flower Moon'**
Use your long lens to record the lovely 'Flower Moon' full Moon, rising at around 9pm on the evening of 18 May.



© Marcus Hansson

5 **Make the most of foreground objects**
If you spot a 'halo' around the Moon on any night, use your wide-angle lens to photograph it. Try to include foreground objects for scale.

6 **Beware of over-processing**
Don't over-process your images, whatever software you use. Aim to keep them as simple and realistic as possible.

10 TIPS TO BEAT LIGHT POLLUTION

It's every astronomer's enemy: here's how to cheat your way to better views of the night sky - even from urban areas

1 Make use of shadow

If you have streetlights shining into your garden, do your best to find a spot that's not illuminated by these which can give you a good view of the sky. Getting into the shadow of a brick wall or a tree can help here. The side of a building can help too, but this can block your view of a large part of the sky, so you may need to hunt around for the best spot in your yard.

2 Wait for the right conditions

Artificial light is shone into the sky and is reflected back to us from dust, water vapour and atmospheric pollution. High humidity or prolonged dry spells when dust can be thrown up into the atmosphere will seem to make the situation worse. Check weather reports and wait for stable conditions with low wind speeds for better viewing.

3 Get out of town

If you have really poor views of the stars most of the time, it might be worth the effort to pack up your equipment and drive a few miles out of your town or city to find darker skies.

4 Shade your optics

If you can't shield yourself from stray light, then you can at least shield the equipment you are using. Dew shields on telescopes, if short, can be extended using thick card, black or dark in colour, and telescope and binocular eyepieces can also be shielded using flexible 'wings', which can usually be obtained from dealers. These will help reduce stray light entering your eye from the side.

5 Cover your head

Another way of shielding yourself from intrusive light is by covering your head with a dark cloth. This is surprisingly effective in getting your eyes dark adapted, allowing the pupil of your eye to dilate as fully as possible. This in turn will mean your eye is as sensitive as it can be to light, and will help you see those faint stars and other objects through your telescope. Don't worry if you think it makes you look daft - no one can see you in the dark!

6 Be nice to your neighbour

This may seem like an odd thing to suggest, but a lot of stray or unwanted light these days comes from security lights. If you have them, turn them off while observing and make sure they point at the ground at other times and, if on timers, make sure they are on for a short a time as is practical. If your neighbours' security lights are troublesome, be polite and ask them to turn them off while you observe. Bring them over to show them what you

© VW Pics / Getty

are looking at – you never know, you might convert them to your hobby!

7 Coloured filters

Coloured filters screw into the bottom of the eyepiece of your telescope. They have lots of good uses in observing, not least that of enhancing details on the Moon and planets. They are also very helpful in reducing the effects of light pollution. This is because they only allow through the wavelengths of light of the specific colour of the filter and block out the other colours, particularly the orange/pink glow of streetlights.

8 Stay out late

It's a fact that stray light reduces as the night wears on. If you are able to stay out late you'll probably find that after midnight the amount of stray light around seems to be less than earlier in the evening. This is due to people going to bed and turning such things as outside lights off. Also some local authorities will turn street lighting down or off after midnight.

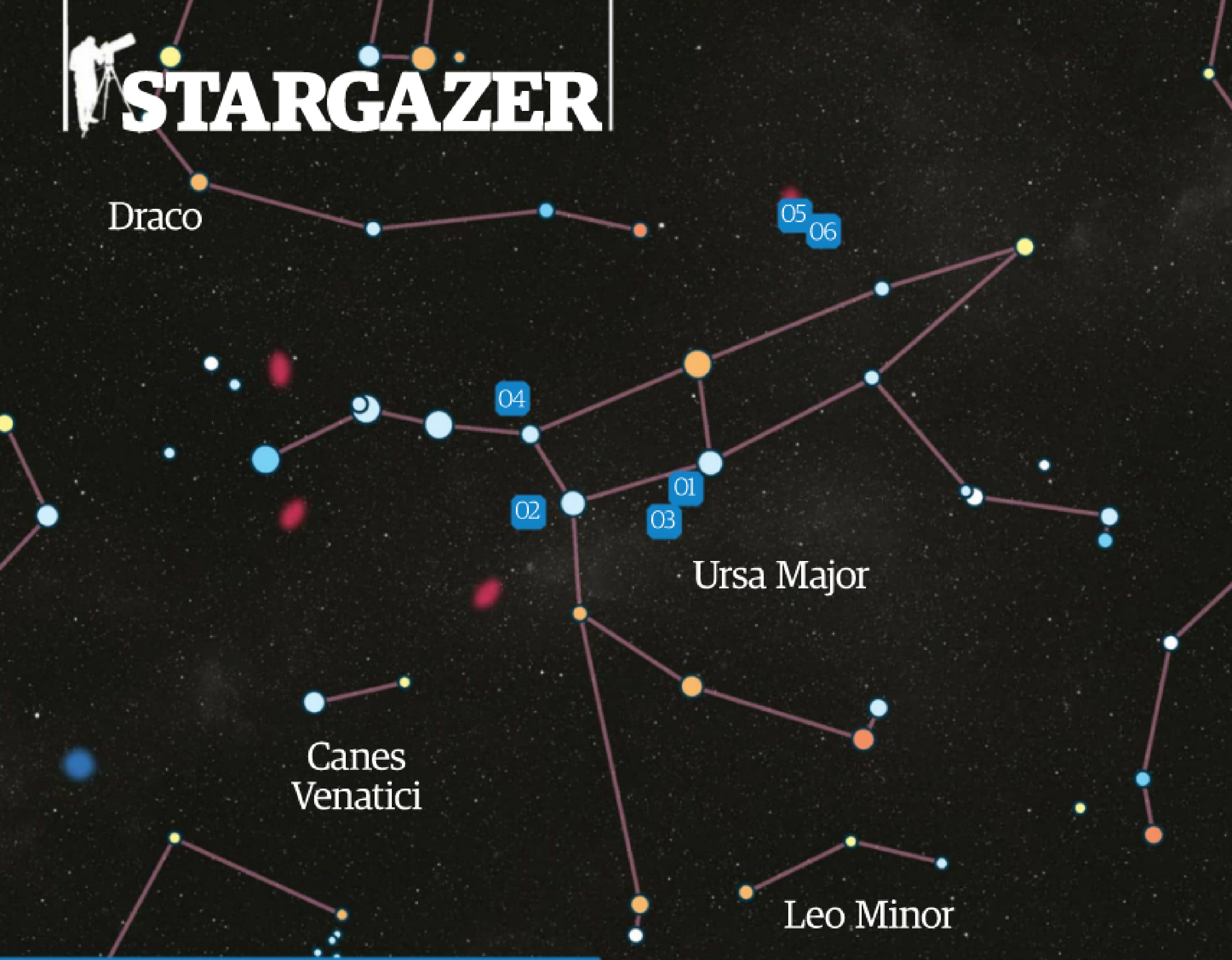
9 Use specialist filters

There are filters specifically designed to help reduce the effects of light pollution for astronomers. These often go by the name of City Light Suppression (CLS) filters or Anti Light Pollution (ALP) filters. These are narrow-band filters that 'tune out' the wavelengths of light emitted by low-pressure sodium streetlights. These can make a significant difference when you are viewing through your telescope.

10 Take up imaging

The beauty of modern digital cameras is that is it relatively easy to manipulate the image produced in software and reduce the orange glow of a city sky with a few clicks of a computer mouse. This is the most expensive option, however, unless you already own a digital SLR (DSLR) camera or a specialist astronomical imaging camera. However, because of the sensitivity of these cameras they can often 'see' more than the human eye in light-polluted conditions.

> "Some local authorities will turn street lighting down or off after midnight"



Deep sky challenge

Hunting for faint fuzzies around the Great Bear

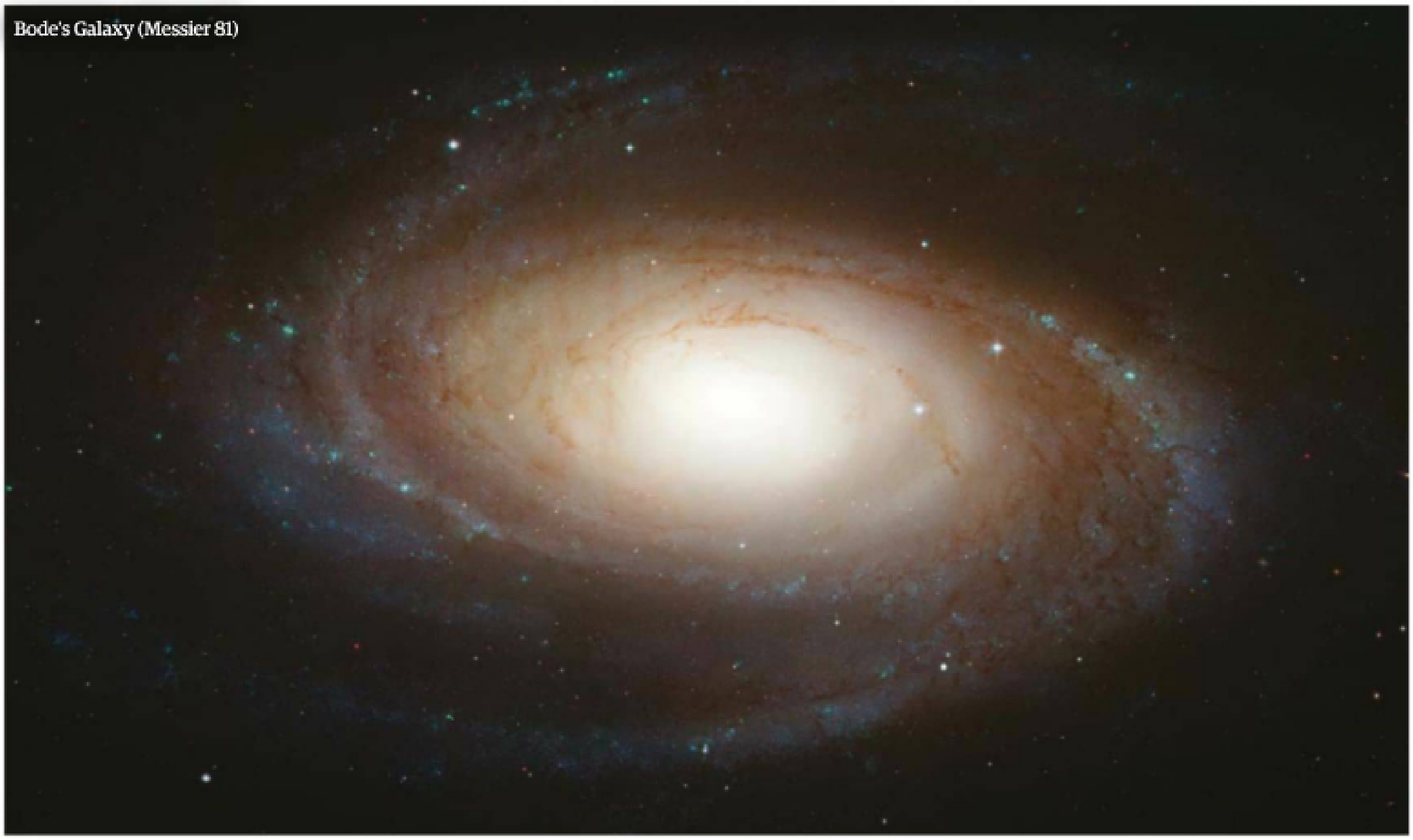
With the Big Dipper hanging overhead, spring nights are perfect for exploring the hidden treasures of Ursa Major

Think of Ursa Major and you probably think of the seven bright naked-eye stars that make up the famous asterism 'The Big Dipper', including the best known double star in the sky – Mizar – and the twin 'Pointers' that point the way to Polaris, The Pole Star, in neighbouring Ursa Minor. But this northern constellation – high overhead as darkness falls on these spring nights – has a lot more to offer.

Lurking inside the boundaries of Ursa Major are many deep-sky objects unfamiliar to and unobserved by many telescope owners. There are plenty of galaxies for observers who like hunting down those faint, distant star cities, and brighter nebulae within our own Milky Way galaxy too.

The Owl Nebula (M97) is very popular with observers of planetary nebulae because it really does resemble the face of a wise old owl when seen through a high-power eyepiece in a large telescope. The close pairing of galaxies M81 and M82 is much loved by owners of small telescopes, but only larger instruments will show detail in the arms and centres of these galaxies.

Messier 109



Bode's Galaxy (Messier 81)

Messier's Mistake (Messier 40)

1 Messier 108

This barred-spiral galaxy is 45 million light years away. Shining at magnitude 10, it is visible as a featureless elongated smudge in 6" telescopes.

2 Messier 109

Magnitude 9.7 and 82 million light years away, this barred-spiral galaxy is a small, pear-shaped blur in small telescopes. Instruments of 6" and larger will show the subtle glow of its spiral arms.

3 The Owl Nebula (Messier 97)

Faint and with a low surface brightness, you will need at least a medium-aperture telescope to see the two dark 'eyes' of this magnitude 9.8 planetary nebula.

4 Messier's Mistake (Messier 40)

This object is an anomaly in Messier's famous catalogue because it is not a galaxy, nebula or cluster, but a close pair of ninth-magnitude stars. It is a 'line of sight' double rather than a genuine binary.

5 Bode's Galaxy (Messier 81)

At magnitude 6.8 this spiral galaxy is bright enough to be visible in binoculars as a tiny smudge, but it takes telescopes of 6" and larger to show its spiral arms and bright core.

6 Cigar Galaxy (Messier 82)

Just over half a degree away from M81, M82 - the Cigar Galaxy - is much smaller and fainter than its more obvious neighbour. A large telescope will reveal light and dark patches along it.

© Will Tillon; NASA, ESA, SDSS, NOAO; Hewbooks;

The Northern Hemisphere

The warmer months have arrived - and an impressive array of targets are to be had

Summer has returned, bringing with it warmer nights. While the cold evenings of winter provide dark skies and longer observing sessions, May still has a lot to offer in the way of vibrant nebulae, star clusters and galaxies. By mid-May at 10pm (BST), the constellations of Canes Venatici (The Hunting Dogs), Virgo (The Virgin), Coma Berenices (Berenice's Hair) and parts of Centaurus (The Centaur) are in prime positions for viewing, offering a splendour of targets. Globular cluster Omega Centauri glows at magnitude 3.9 and makes its appearance from the east to set in the west. NGC 5128, or Centaurus A, contains multiple layers of dust and is one of the brightest galaxies in the sky - you'll need your 'scope to see the detail.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

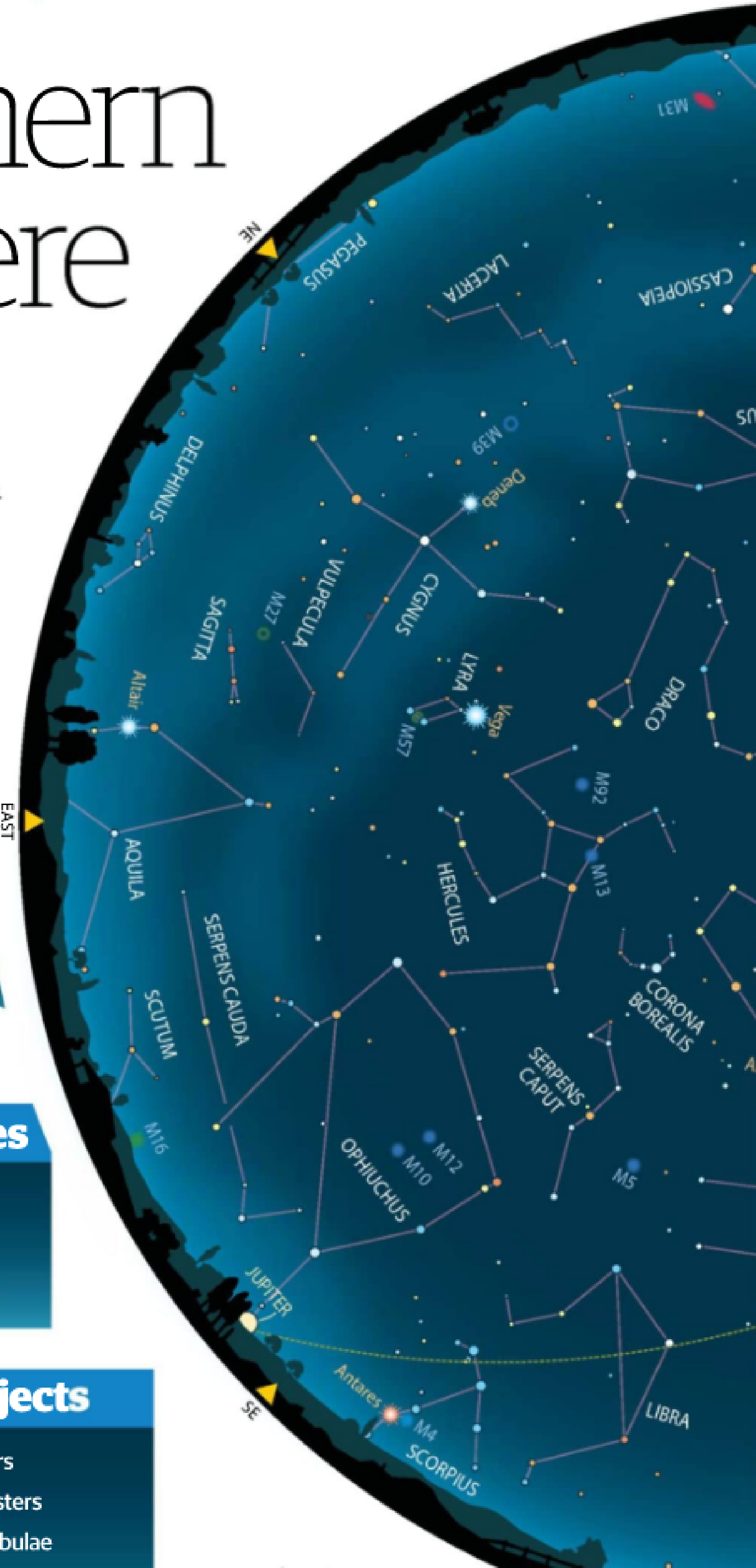
- ✸ Sirius (-1.4)
- ✸ -0.5 to 0.0
- ✸ 0.0 to 0.5
- ✸ 0.5 to 1.0
- ✸ 1.0 to 1.5
- • 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- • 3.0 to 3.5
- · 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- ○ Variable star

Spectral types

- ✸ • O-B
- ✸ • A
- ✸ • F
- ✸ • G
- ✸ • K
- ✸ • M

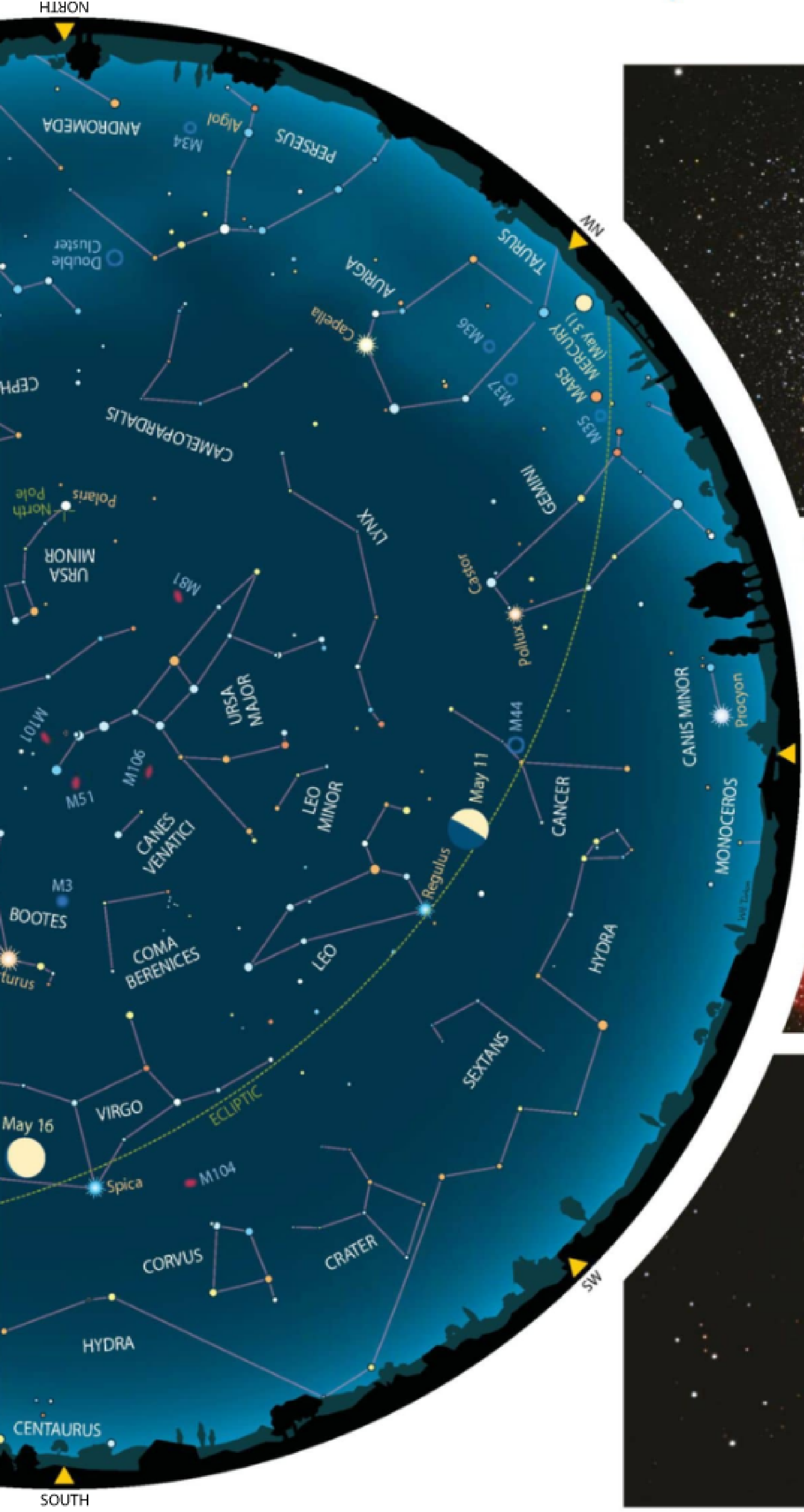
Deep-sky objects

- ○ ○ Open star clusters
- ● ● Globular star clusters
- ■ ■ Bright diffuse nebulae
- ○ ○ Planetary nebulae
- ● ● Galaxies



Observer's note: The night sky as it appears on 16 May 2019 at approximately 10pm (BST).

STARGAZER
The Northern Hemisphere



Messier 3

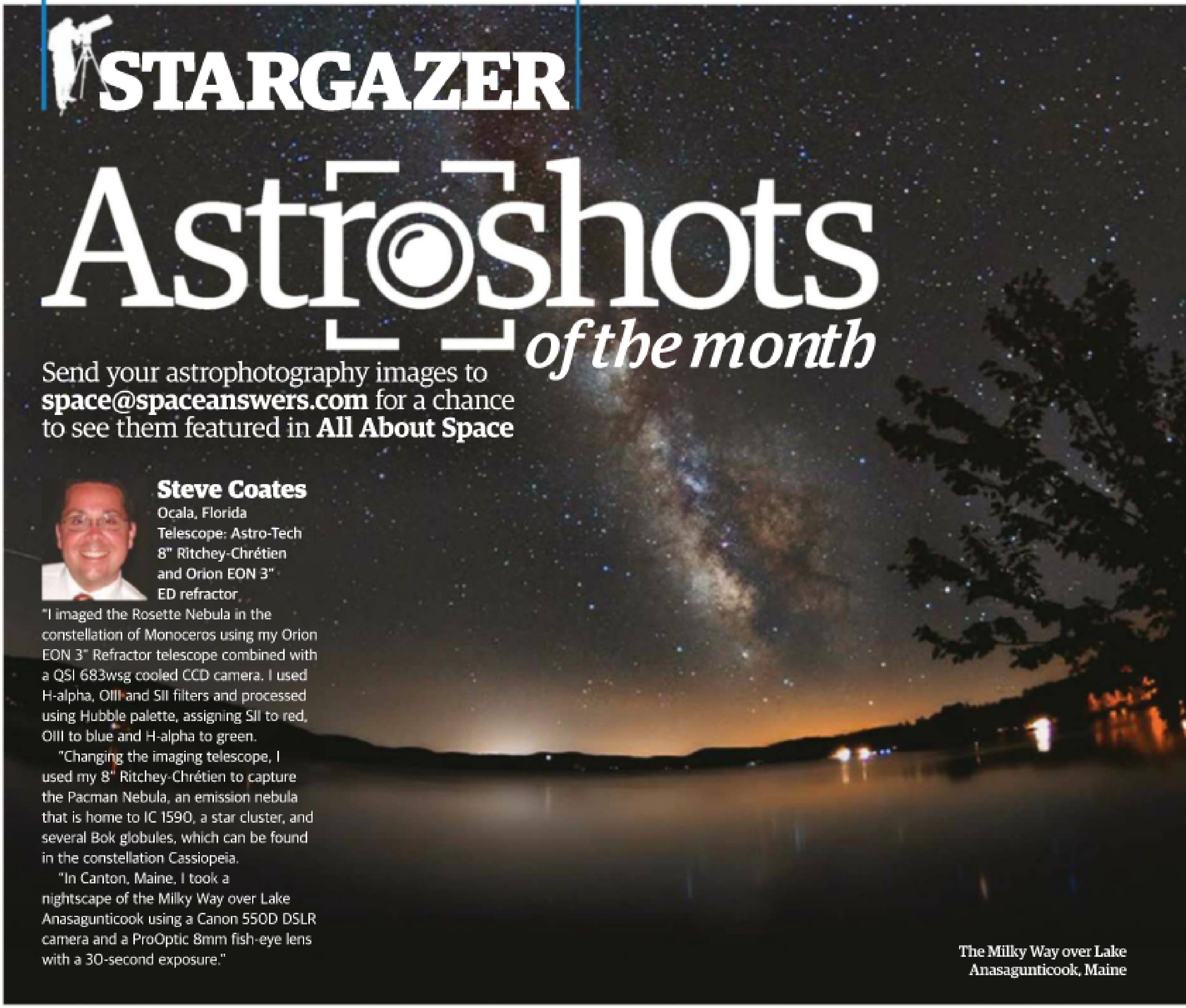
Running Chicken Nebula (IC 2944)

NGC 4361

© Wil Tirion; ESO; Adam Block/Mount Lemmon SkyCenter/University of Arizona

Astroshots of the month

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**



Steve Coates

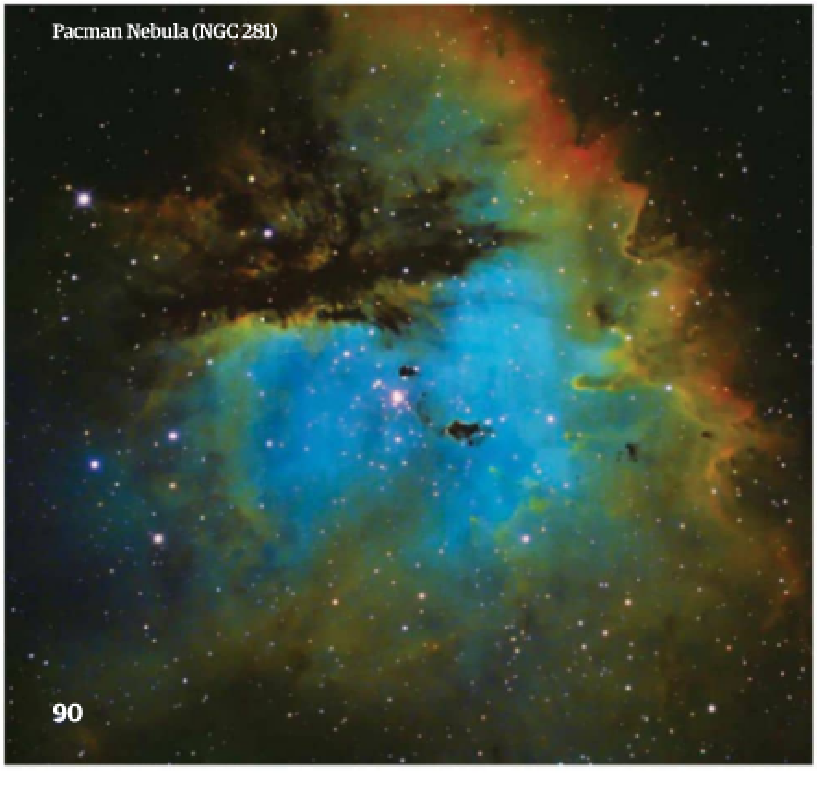
Ocala, Florida
Telescope: Astro-Tech 8" Ritchey-Chrétien and Orion EON 3" ED refractor

"I imaged the Rosette Nebula in the constellation of Monoceros using my Orion EON 3" Refractor telescope combined with a QSI 683wsg cooled CCD camera. I used H-alpha, OIII and SII filters and processed using Hubble palette, assigning SII to red, OIII to blue and H-alpha to green.

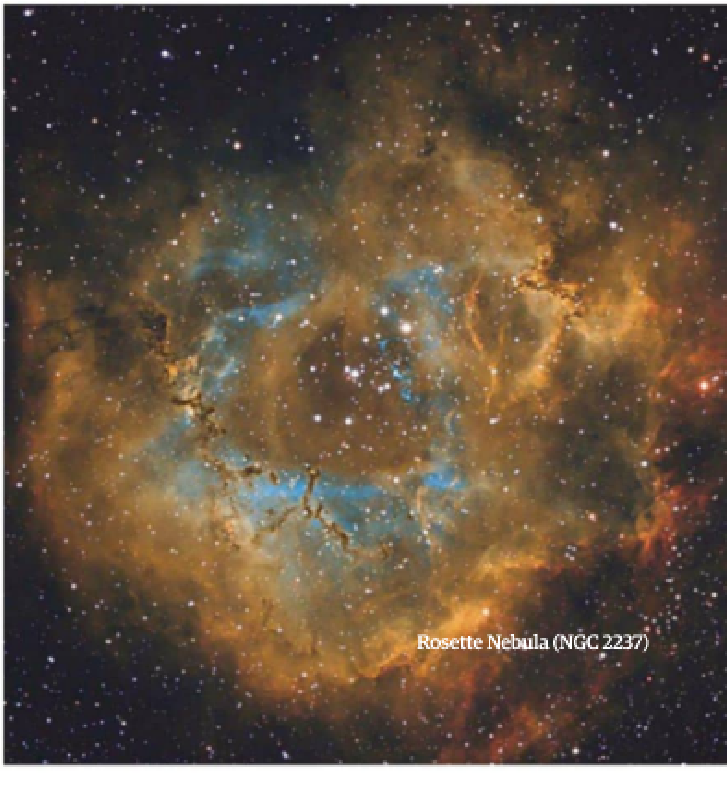
"Changing the imaging telescope, I used my 8" Ritchey-Chrétien to capture the Pacman Nebula, an emission nebula that is home to IC 1590, a star cluster, and several Bok globules, which can be found in the constellation Cassiopeia.

"In Canton, Maine, I took a nightscape of the Milky Way over Lake Anasagunticook using a Canon 550D DSLR camera and a ProOptic 8mm fish-eye lens with a 30-second exposure."

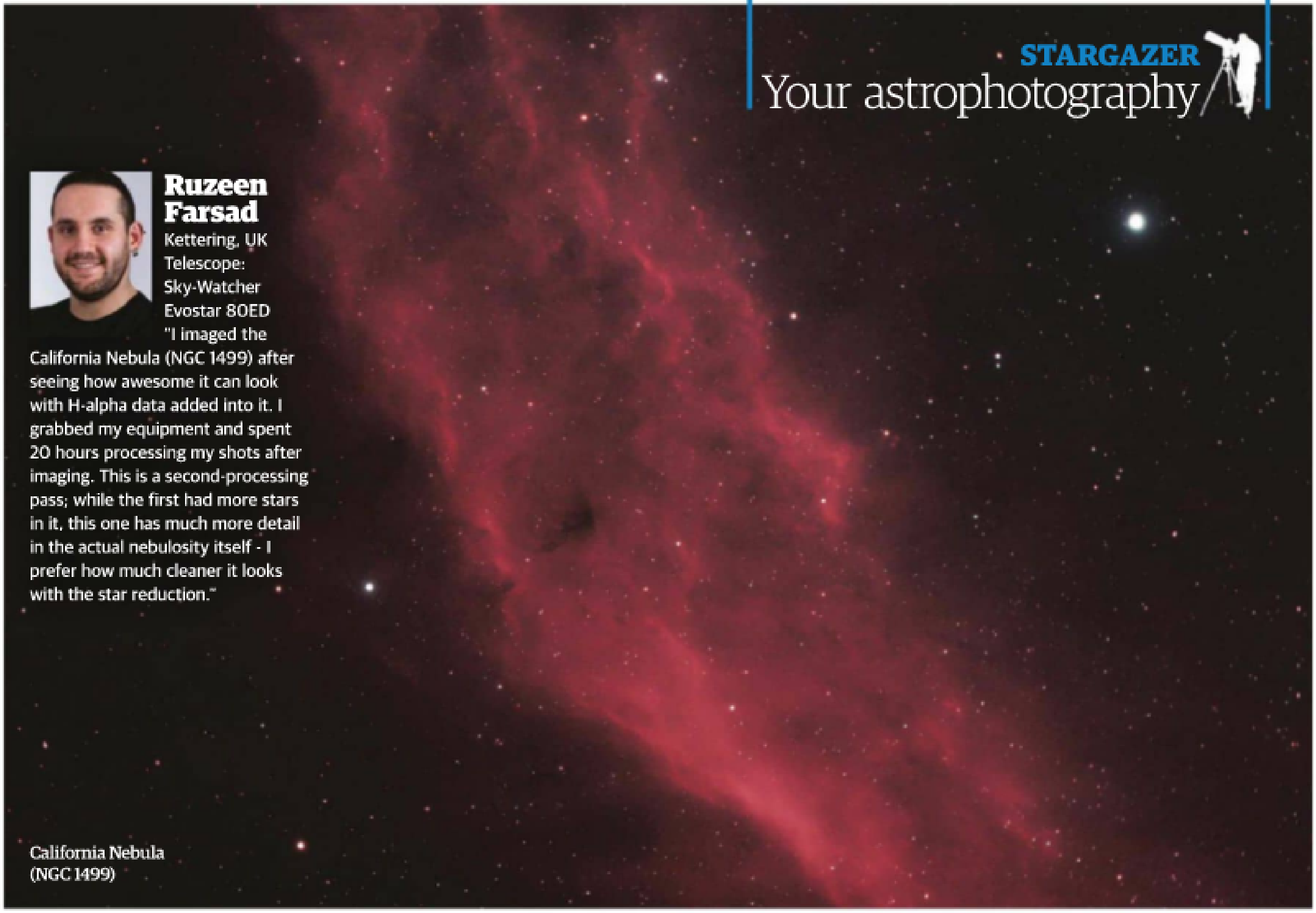
The Milky Way over Lake Anasagunticook, Maine



Pacman Nebula (NGC 281)



Rosette Nebula (NGC 2237)

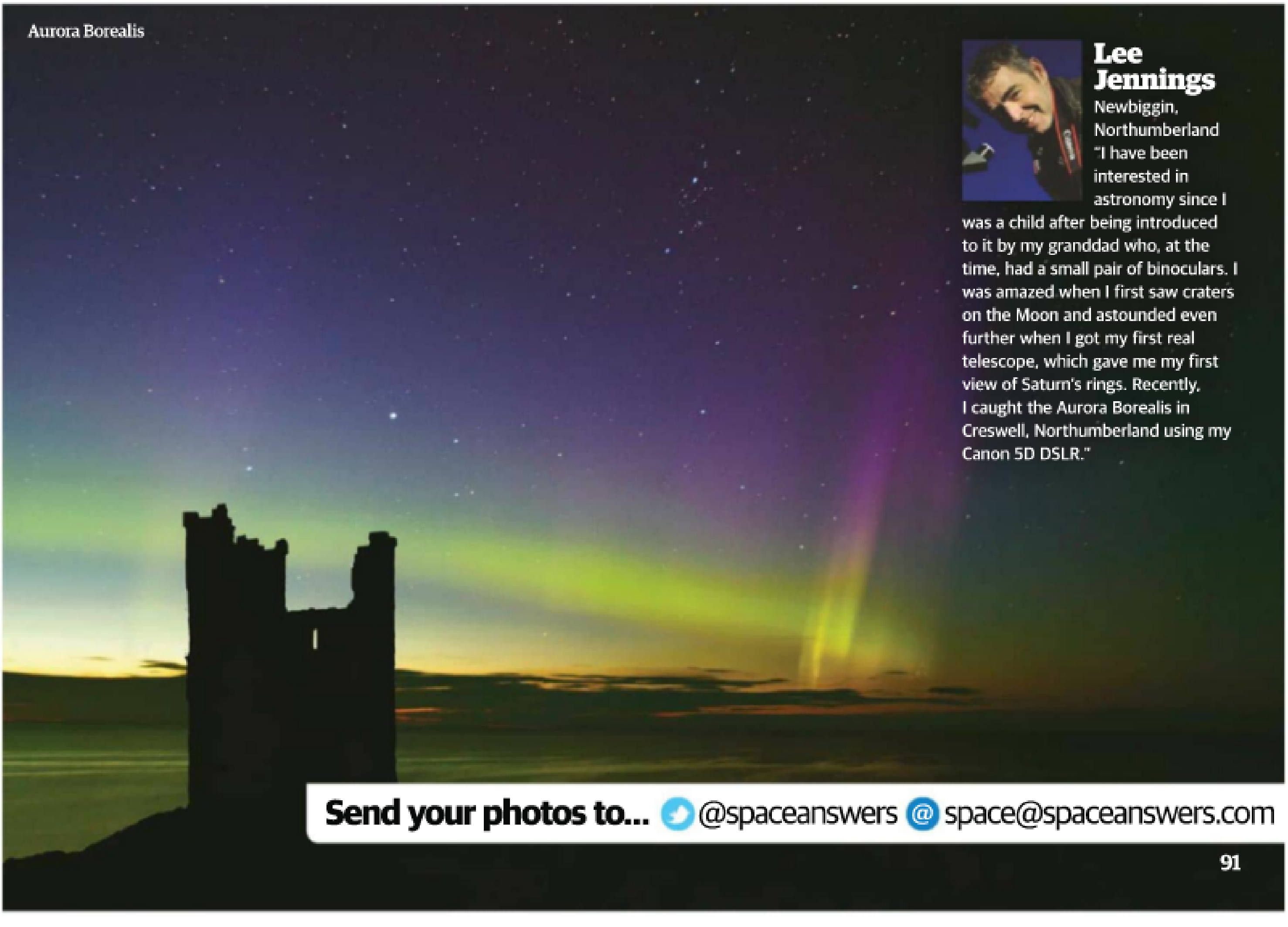


Ruzeen Farsad

Kettering, UK
Telescope: Sky-Watcher Evostar 80ED

"I imaged the California Nebula (NGC 1499) after seeing how awesome it can look with H-alpha data added into it. I grabbed my equipment and spent 20 hours processing my shots after imaging. This is a second-processing pass; while the first had more stars in it, this one has much more detail in the actual nebulosity itself - I prefer how much cleaner it looks with the star reduction."

California Nebula (NGC 1499)



Aurora Borealis

Lee Jennings

Newbiggin, Northumberland

"I have been interested in astronomy since I was a child after being introduced to it by my granddad who, at the time, had a small pair of binoculars. I was amazed when I first saw craters on the Moon and astounded even further when I got my first real telescope, which gave me my first view of Saturn's rings. Recently, I caught the Aurora Borealis in Creswell, Northumberland using my Canon 5D DSLR."

Send your photos to... @spaceanswers space@spaceanswers.com

Sky-Watcher Startravel-102 (AZ-GTe)

Designed to be controlled wirelessly with your smartphone, this highly portable refractor provides good Solar System views

Telescope advice

Cost: £379 / $496
From: Optical Vision
Type: Refractor
Aperture: 4.02"
Focal length: 19.69"

Best for...

- Beginners
- Small budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky

There are all kinds of factors that mean we live rushed observing lives, from the constant threat of encroaching clouds to the demands on our time from general life and work. Often when we go out under the stars, we want a 'scope that's portable and quick to set up.

Sky-Watcher's Startravel-102, which comes on an AZ-GTe Go-To alt-az mount and an adjustable steel tripod, is the perfect 'grab-and-go' scope for beginners or casual observers. Weighing just 6.7 kilograms, it's easy to carry outside – though if possible, and not too rushed, allow half an hour for it to acclimatise to the ambient temperature outside to avoid heat currents from the telescope disturbing the view. Its most high-profile feature is its Wi-Fi capability, allowing you to control the telescope easily from your own smartphone, tablet or laptop. Once the mount is powered up using either eight AA batteries or a 14V external supply, it creates its own Wi-Fi network that you can connect to. However, you do need to first download Sky-Watcher's free SynScan app to control the telescope wirelessly. A little red LED light on the mount blinks on to let you know you're connected.

The next step is to align the telescope so that the Go-To system knows where it is pointing in the sky. The system automatically gets the date, time and location from your phone or tablet's GPS, meaning you don't need to input these manually. Next, select a region of the sky, at which time you'll be prompted to slew to a bright star in that region, using the finderscope to guide you. Once the telescope is aligned on that star, the Go-To will automatically slew to several other stars until it confirms a successful alignment. Now you're ready to start using it!

The Startravel-102, with an aperture of 102mm (four inches) and a focal length of 500mm, has a reputation for being a great wide-field telescope, and this was borne out in our tests. We began with the Beehive Cluster, also known as M44, which looked great; the pinpoint stars of this open cluster in Cancer, the Crab, seemed to sparkle as they filled the field of view through the 10mm 1.25" eyepiece that comes with the telescope. Both the 10mm and the 25mm that also comes with it are fairly standard – they are okay to begin with, but anyone intent on doing any serious observing will likely swap them out for their own better quality eyepieces.

Springtime is, of course, the best time of the year for viewing galaxies, particularly those that litter the constellations of Virgo, Leo and Coma Berenices. However, this is where the limitations of a rich-field telescope come into play. The brighter galaxies of the Virgo Cluster are mostly under ten arcseconds in angular diameter, and when viewed they appeared as diffuse blobs, lost in the wide field. The dramatic face-on spiral of the Whirlpool Galaxy fared a little better, but best was Messier 81, a spiral in Ursa

Right: The Sky-Watcher Startravel-102 is suitable for a selection of deep-sky targets

Right (inset): The refractor features a SynScan hand control port

Bottom left: The telescope comes supplied with 10mm and 25mm eyepieces

Bottom right: The Startravel is supplied with a red dot finder, making star-hopping an easy feat

> "The Startravel-102 has a reputation for being a great wide-field telescope, borne out in our tests"

Major, its 27 arcminute diameter faring much better in the field of view, showing a fuzzy disc and a definite brighter concentration at its centre. In the same field of view, the nearby edge-on Cigar Galaxy, Messier 82, appeared small, but its higher surface brightness meant it held its own against M81.

Refracting telescopes inherently suffer from chromatic aberration – a colour fringing around bright objects caused by different wavelengths of light, or different colours – and focus slightly differently, resulting in colourful haloes around objects. Planets and the Moon in particular suffer from this when viewed through a refractor, and the Startravel-102 is no different. March's supermoon came on a rare, relatively cloudless night. Full Moon isn't always the best time for observing features on the Moon, but the distinctive fringe of purple resulting from chromatic aberration was noticeable on the lunar limb. For serious planetary observers and imagers it would be problematic, but we've seen worse chromatic aberration, and for casual observers the level of colour fringing is reasonable.

The SynScan database contains more than 10,000 objects: to be precise, 10,759 deep-sky objects like galaxies and nebulae, including all of the NGC, IC, Messier and Caldwell catalogues; 305 named stars; 55 double stars and all the planets of the Solar System, plus the Moon and the Sun – but do not look at the Sun without a suitable solar filter!

We found that the telescope's Go-To was able to find every object that we targeted relatively easily. It has nine slewing speeds, and it's not the quietest, but the telescope found every object we wanted, although most required a little bit of fine tuning to centre the object. The tripod is sturdy and can be extended to heights between 0.8 and 1.5 metres. On the telescope, the aforementioned eyepieces provide magnification of 20x and 50x, while the rack-and-pinion focuser is fairly decent, especially for the price.

The Startravel-102 is a great beginners telescope or a grab-and-go telescope for those wanting to observe in a hurry. While deep-sky enthusiasts may quickly outgrow it, for everyone else it is an excellent introduction to the world of refractors.

WIN

SKY-WATCHER STARTRAVEL-102 (AZ-GTE)

This refractor telescope – with its excellent built-in WiFi and Go-To control – is ready to revolutionise your experience

Sky-Watcher is a brand universally loved because of its unique designs, its ease of transportation and assembly and its fine optics, capable of revealing a catalogue of marvellous celestial objects. Now, courtesy of Optical Vision Ltd, one of its Startravel refractor telescopes, flaunting a 102-millimetre (four-inch) aperture and AZ-GTe mounting, is waiting to lead you into a new realm of astronomy.

The Startravel-102 telescope is fitted with its own WiFi module and Go-To control, meaning that it can be controlled using any tablet or smartphone via the SynScan app, available for both iOS and Android. This can show any astronomer over 10,000 celestial objects with just the press of an option on your handheld device. Eyepieces also included in the package.

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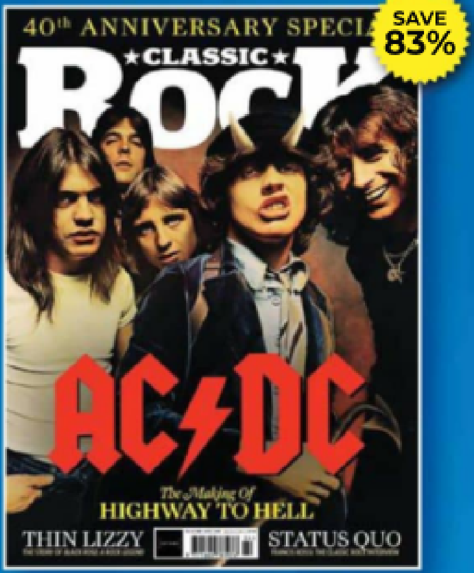

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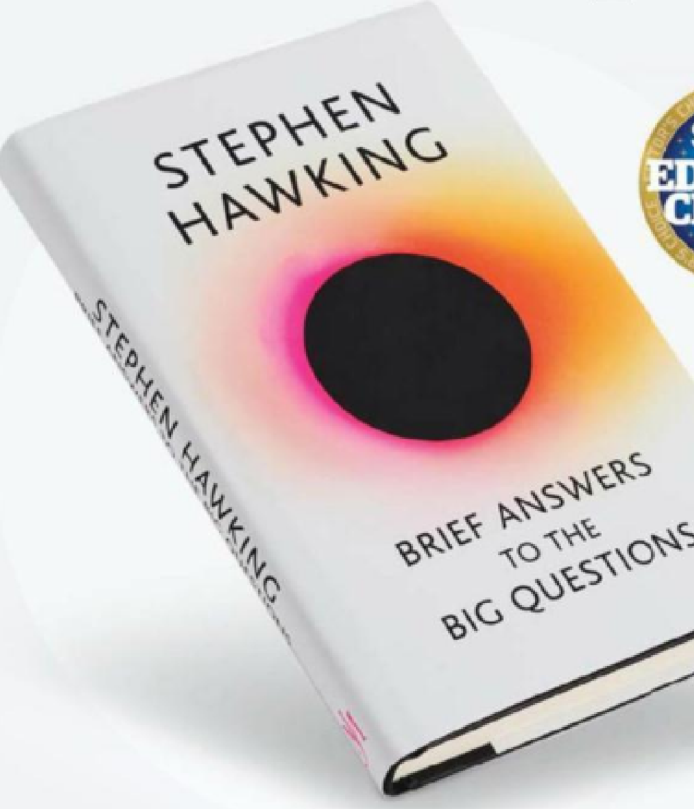
In the shops

The latest books, apps, software, tech and accessories for space and astronomy fans alike



Book Brief Answers to the Big Questions

Cost: £14.99 (approx. $19.60)
From: John Murray

The world-famous cosmologist and number one bestselling author of A Brief History of Time leaves us with his final thoughts on the universe's biggest questions in this brilliant posthumous work. Is there a God? How did it all begin? Can we predict the future? What is inside a black hole? Is there other intelligent life in the universe? Will AI outsmart us? How do we shape the future? Will we survive on Earth? Should we colonise space? Is time travel possible?

Throughout his extraordinary career, Stephen Hawking expanded our understanding of the universe and unravelled some of its greatest mysteries. But even as his theoretical work on black holes, imaginary time and multiple histories took his mind to the furthest reaches of space, Hawking always believed that science could also be used to fix the problems on our planet. And now, as we face potentially catastrophic changes here on Earth - from climate change to dwindling natural resources to the threat of artificial super-intelligence - Stephen Hawking turns his attention to the most urgent issues for humankind. Wide-ranging, intellectually stimulating, passionately argued and infused with his characteristic humour, it's a must-read.

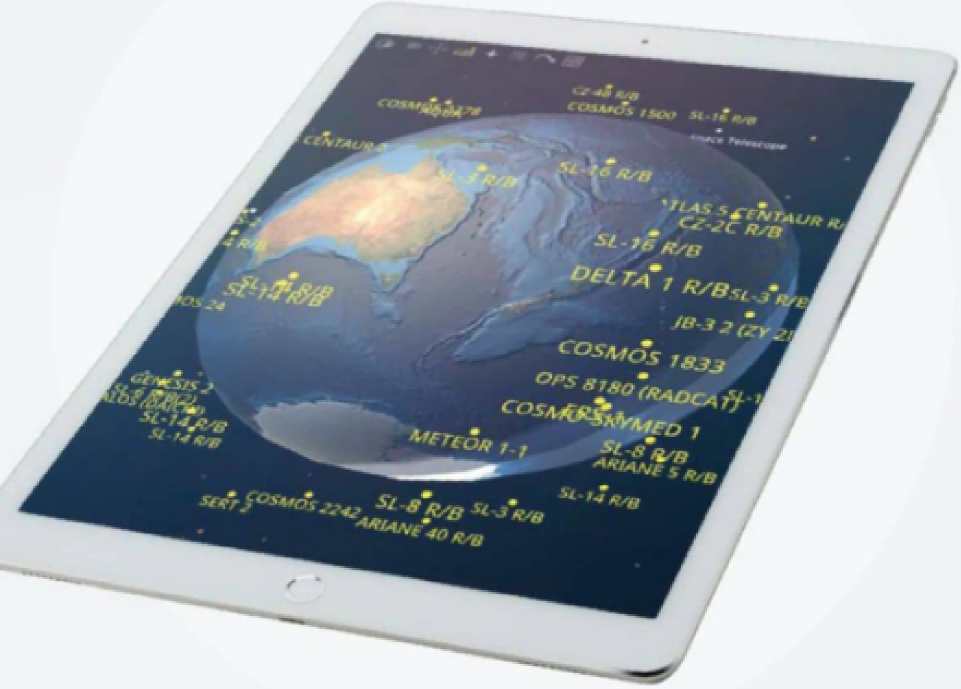
All About Space EDITOR'S CHOICE

Software Universe Sandbox^2

Cost: £18.99 ($24.99)
From: Steam

A space simulator that can be downloaded to your computer, *Universe Sandbox*^{2} is ideal for those who are keen to mix their love of gaming and the universe. Unlike many games on the market, *Universe Sandbox*^{2} doesn't have an overall mission, but you can have endless fun creating universes or playing with existing ones and the objects within them. On the whole the developers have impressively ensured that all the components (excluding the teapots) within this virtual cosmos - including planets, comets and stars - act as they should when obeying the laws of physics. If the user alters the systems in any way, chaos unfolds, revealing how the Solar System and even our galaxy could be affected if the balance of the universe was upset even slightly.

In general, the premise of the game is simple: put various rocks in space, set various physical properties, including velocity, mass and density, then watch them get to work. Whatever you decide to do - whether its making the Earth the same size as the Sun, throwing Mercury past the orbits of Uranus and Neptune or blowing up Jupiter - *Universe Sandbox*^{2} is certainly worth a play.



App Space Junk Pro

Cost: £2.99 (approx. $3.89) **From:** iOS and Android
We very much like the idea behind Space Junk Pro, which uses satellite data to show you which planets, satellites and constellations are viewable in your sky at any one time.

We were particularly impressed with the way in which Space Junk Pro was able to locate the International Space Station (ISS), and even the Hubble Space Telescope, making it a sure favourite for anyone who has ever found themselves rushing outside to witness the ISS racing around our planet in its orbit.

Smoothly uploading the app onto an iPhone and ensuring that our device's compass was calibrated, we found no issues with the running of Space Junk Pro. However, we did find that it drains phone batteries quite quickly and automatically starts up without prompting when we switched on our device. This might be off-putting for some, but overall the app is an excellent piece of software for a very good price. It could also prove to be a handy educational tool in explaining the shapes and motions of the Solar System.

> "Elaborate plans for human exploration of Mars are also shown in exquisite detail"

Book Mars

Cost: £25 (approx. $32.69) **From:** Andre Deutsch Ltd
All eyes are on Mars. NASA's new lander, InSight, has touched down on the Red Planet, and in two years the Mars 2020 rover will depart Cape Canaveral bound for Mars. The ultimate challenge is to enable crewed missions to Mars by the 2030s - the next giant leap for mankind. In *Mars*, NASA historian and award-winning space writer Rod Pyle takes us through uncharted territory to experience the unravelling of the mysteries of the Red Planet first-hand and as they happened.

With unparalleled access to NASA's archives, he traces the exploration of the Red Planet from fleeting telescopic examinations of the first flybys in the 1960s, through the landers of the 1970s, to the increasingly sophisticated rovers and orbiters now exploring every region of the planet. Insider documents from NASA's Jet Propulsion Laboratory, including newly found hand-drawn renderings of mission designs and personal annotations, illustrate every aspect of 50 years of discovery. The elaborate plans for human exploration of Mars are also shown in exquisite detail, including NASA's ambitious designs for crewed missions and some compelling alternative mission plans by experts such as Buzz Aldrin.

ROD PYLE
Foreword by James Green
NASA Chief Scientist
MARS
THE MISSIONS THAT HAVE TRANSFORMED OUR UNDERSTANDING OF THE RED PLANET

Andriyan Nikolayev

Nicknamed the 'Iron Man', Nikolayev was one of the pioneering cosmonauts in the early 1960s

Andriyan Nikolayev is not as much of a household name as Yuri Gagarin, but his accomplishments should not go under the radar. His record-breaking Vostok 3 mission pushed the boundaries of the human body in zero gravity.

Nikolayev was born on 5 September 1929 in Sorseli, formerly of the Soviet Union and currently of Chuvashia, Russia. The former lumberjack began cosmonaut training in March 1960 along with Gagarin and Gherman Titov. Around the same time Nikolayev began a relationship with Valentina Tereshkova, who later became the first woman in space. She and Nikolayev were married in 1963.

Gagarin was the first person in space with the Vostok 1 mission on 12 April 1961, and Titov the second Soviet cosmonaut in space with the Vostok 2 mission on 6 August 1961. Finally Nikolayev got his chance with Vostok 3 on 11 August 1962 – a year after the Vostok 2 mission.

The Vostok 3 mission was designed to test the endurance of the Vostok spacecraft and the human body in weightlessness. How would the body function beyond the confines of gravity? In modern times, with the constant presence of the International Space Station, this question is understood more clearly, but in the early 1960s, before Apollo triumph, it was an extreme unknown. Nikolayev played a huge part in the Soviets' understanding of weightlessness as his Vostok 3 mission kept him in space for an impressive three days and 22 hours. This was a length of time that NASA didn't accomplish until roughly four years later with the Gemini program.

While in space Nikolayev was able to communicate with Earth, and even sent a wireless greeting to President Khrushchev. On his first day in space he conducted the first live TV broadcast from space and manually operated the spacecraft twice. During this time Pavel Popovich made his ascent into space aboard the Vostok 4 mission, making it the first time ever that two manned spacecraft were in space simultaneously.

On 15 August 1962, Nikolayev re-entered the Earth's atmosphere and landed safely in Kazakhstan to a hero's welcome. It wouldn't be until 1970 when he made his return to space aboard the Soyuz 9 spacecraft. This was a much longer stay in space; he spent 17 days and 16 hours with flight engineer Vitaly Sevastyanov, absolutely shattering the previous record held for time in space, which was five days set by Gemini 7.

Nikolayev had outstanding endurance for this sort of thing, something that led him to the nickname 'Iron Man', coined from his training days when he spent extraordinary amounts of time in isolation chambers. After Soyuz 9, Nikolayev underwent no other spaceflights. He was given the 'Hero of the Soviet Union' title twice, one after each spaceflight. He sadly passed away from a heart attack on 3 July 2004 in Cheboksary, the capital of his native Chuvash Autonomous Republic.

Nikolayev underwent two spaceflights: Vostok 3 and Soyuz 9

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> "Vostok 3 was designed to test the endurance of the Vostok spacecraft and the human body in weightlessness"

All About Space

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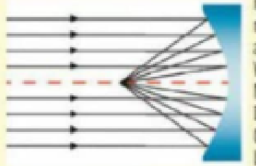

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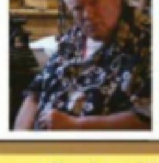

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